



COOPERATING TO IMPLEMENT THE GREAT LAKES WATER QUALITY AGREEMENT
MISE EN OEUVRE DE L'ACCORD SUR LA QUALITÉ DE L'EAU DES GRANDS LACS

Dear Friends of the Great Lakes,

Please note that the enclosed report presents information and assessments on 33 of the 80 indicators, as well as Lake-by-Lake assessments. There are however, 35 separate assessments in the report, including the Table in the Executive Summary. Walleye and *Hexagenia* assessments represent **one indicator** but were reported separately in the report. The same situation applies for Lake Trout and Scud (*Diporeia hoyi*).

Please also note that on page 49 the top figure caption should read "Lake Ontario Actual Levels". The bottom figure caption should read "Lake Michigan-Huron Actual Levels". The overall figure caption should read "Actual water levels for Lakes Huron and Michigan (lower) and Lake Ontario (upper)"

A CD-ROM accompanies this report and includes background reports, documents and presentations which have assisted in the development of the *State of the Great Lakes* (2001).

The *State of the Great Lakes* report, can be also be found at the following web site:

<http://www.binational.net>

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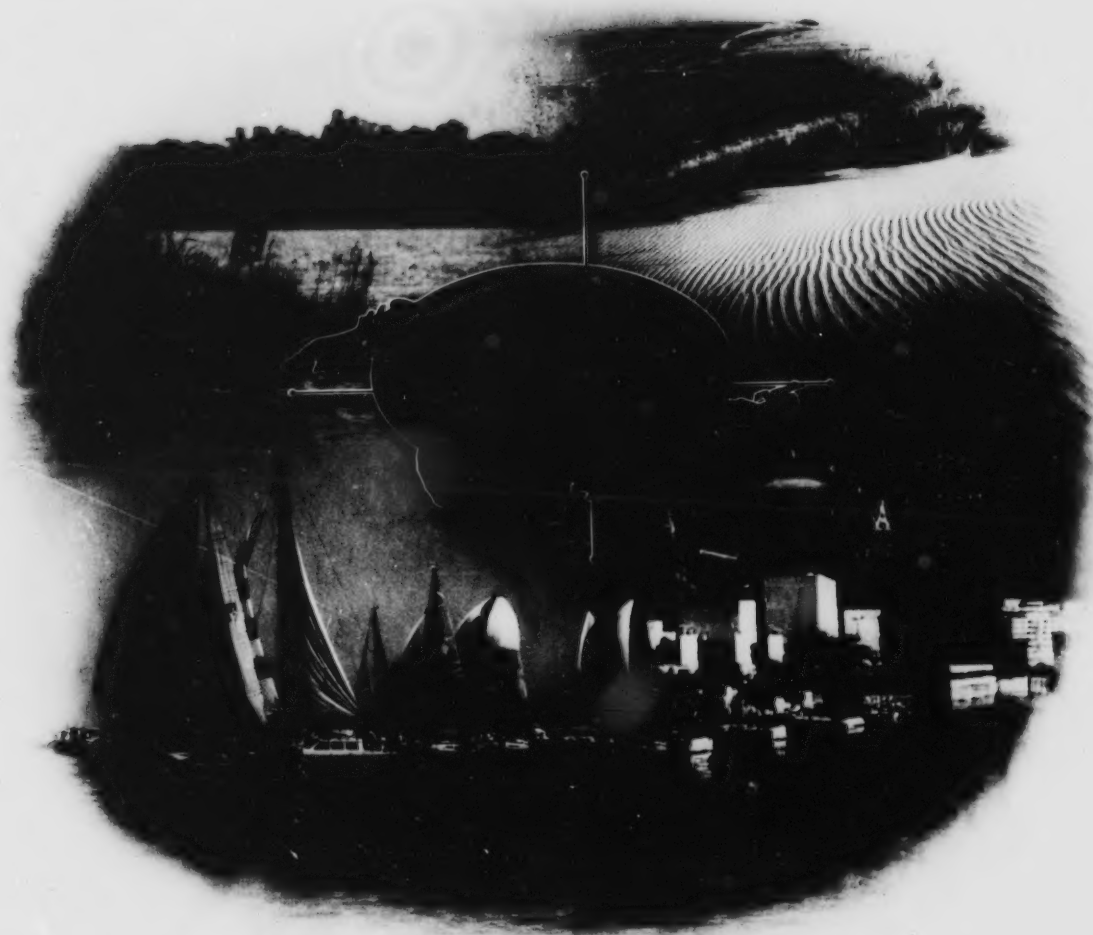
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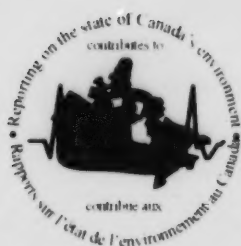


STATE OF THE GREAT LAKES 2001



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and
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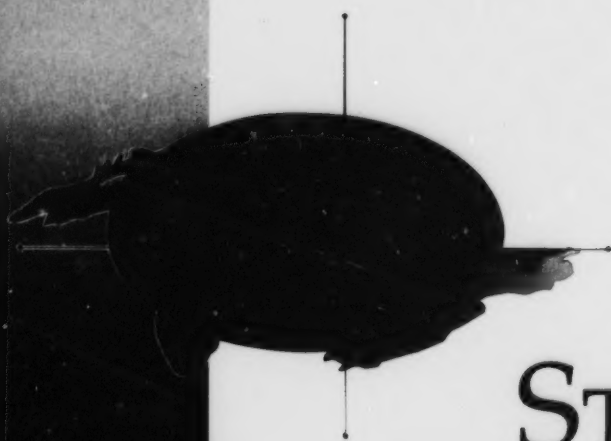
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The *State of the Great Lakes 2001* carries the Canadian State of Environment (SOE) reporting symbol, because this report satisfies the guidelines for the Government of Canada's SOE reporting program. The two purposes of SOE reports are to 1) foster the use of science in policy- and decision-making and 2) to report to Canadians on the condition of their environment. *The State of the Great Lakes 2001* meets SOE reporting requirements by providing an easily understood overview of the state of the Great Lakes basin ecosystem for the non-scientist; examining the key trends in the Great Lakes basin ecosystem; providing a set of environmental indicators; and discussing links amongst issues.

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Blue Heron, Don Breneman
Sleeping Bear Dunes, Robert De Jonge, courtesy Michigan Travel Bureau
Port Huron Mackinac Race, Michigan Travel Bureau
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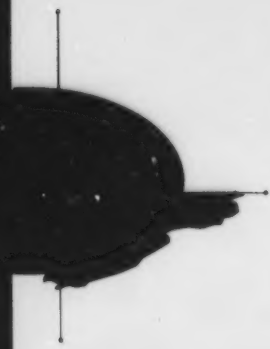


STATE OF THE GREAT LAKES 2001

by the Governments of
Canada
and
the United States of America

Prepared by
Environment Canada
and the
U.S. Environmental Protection Agency





A Promise to Future Generations

Created by the student delegates of the 2001 Great Lakes Student Summit
May 9-11, 2001
Buffalo, New York

We, the students of the Fourth Biennial Great Lakes Student Summit, embark on the new millennium with this solemn and heartfelt promise:

We promise to continue our quest for knowledge related to the Great Lakes and the environment.

We promise to support recycling efforts and encourage our friends and family to recycle and reduce waste.

We promise to join in community clean-ups, beach sweeps, tree plantings and other restoration efforts.

We promise to reduce our use of energy and natural resources and encourage those around us to do the same.

We promise to practice water conservation, pesticide reduction and other environmentally friendly practices and convince our families and peers to join our efforts.

We promise to make others aware of the problems of the Great Lakes and try to convince them to work towards addressing these problems.

We promise to protect the habitats around the Great Lakes, especially wetlands and other environmentally sensitive areas.

We promise to make political leaders more aware of environmental issues and concerns, so that we can keep the Great Lakes healthy for generations to come.

We promise to encourage stronger and more meaningful cooperation among the Great Lakes states and the Province of Ontario.

We promise to put the needs of the Great Lakes and the environment before our own personal needs.

We promise to make a conscious effort to respect all living and non-living components of our watershed.

Finally, we promise to give back to the Earth more than we take from it.



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Executive Summary

This State of the Great Lakes (2001) report is the fourth biennial report issued by the governments of Canada and the United States of America (the Parties to the Great Lakes Water Quality Agreement), pursuant to reporting requirements of the Agreement. Previous reports presented information on the state of the Lakes based on ad hoc indicators suggested by scientific experts involved in the State of the Lakes Ecosystem Conferences (SOLEC). In 1996, those involved in SOLEC saw the need to develop a comprehensive, basin-wide set of indicators that would allow the Parties to report on progress under the Agreement in a comparable and standard format.

Indicators will tell us whether we are meeting the goals of the Great Lakes Water Quality Agreement ("...to restore and maintain the chemical, physical, and biological integrity of the waters of the Great Lakes Basin Ecosystem"), and provide us with answers to 'simpler' questions such as: Can we drink the water?; Can we eat the fish?; and Can we swim in the water? Indicators help us to measure our progress towards reaching our goals, or, alternatively, how far we have left to go.

This report represents the first in the indicator-based format, giving information on 33 of the 80 indicators being proposed by the Parties. These 33 indicators were selected because data for them were readily available with the individual indicator reports prepared by subject experts.

Not all of the proposed 80 indicators are presently being monitored. This situation represents a challenge to the Parties to ensure that information is available in a timely fashion to allow reporting on progress on all indicators, at a frequency suitable for each indicator. It is essential that monitoring systems be put in place to ensure collection of all essential information applicable to each indicator.

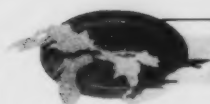
A full description of the indicators is in the *Selection of Indicators for Great Lakes Basin Ecosystem Health, Version 4*.

The Parties cannot provide a detailed quantitative assessment of all aspects of the State of the Lakes based on 33 of 80 indicators. Nevertheless, the Parties make the following overall qualitative assessment:

The status of the chemical, physical, and biological integrity of the waters of the Great Lakes basin ecosystem has been assessed and is considered mixed because:

- Surface waters are still amongst the best sources of drinking water in the world;
- Progress has been made both in cleaning up contaminants and in rehabilitating some fish and wildlife species;
- Invasive species continue as a significant threat to Great Lakes biological communities;
- Atmospheric deposition of contaminants from distant sources outside the basin confound efforts to eliminate these substances;
- Urban sprawl threatens high quality natural areas, rare species, farmland and open space; and
- Development, drainage, and pollution are shrinking coastal wetlands.

The assessments for each of the 33 indicators are on the following page. The section that follows the Executive Summary contains implications for managers. This section was prepared in order to meet one of the SOLEC objectives: "...to strengthen the decision-making and environmental management concerning the Great Lakes."



STATE OF THE GREAT LAKES 2001

Indicator Name	Indicator ID #	SOLEC Category	Assessment *
Walleye	9	Nearshore & Open Waters	Good
Contaminants in Colonial Nesting Waterbirds	115	Nearshore & Open Waters	Good
Drinking Water Quality	4175	Human Health	Good
Hexagenia	9	Nearshore & Open Waters	Mixed, improving
Atmospheric Deposition of Toxic Chemicals	117	Nearshore & Open Waters	Mixed, improving
Contaminants Affecting Productivity of Bald Eagles	8135	Nearshore Terrestrial	Mixed, improving
Brownfields Redevelopment	7006	Land Use	Mixed, improving
Chemical Contaminants in Edible Fish Tissue	4083	Human Health	Mixed, improving
Preyfish Populations	17	Nearshore & Open Waters	Mixed
Spawning-Phase Sea Lamprey Abundance	18	Nearshore & Open Waters	Mixed
Lake Trout	93	Nearshore & Open Waters	Mixed
Phosphorus Concentrations & Loadings	111	Nearshore & Open Waters	Mixed
Toxic Chemical Concentrations in Offshore Waters	118	Nearshore & Open Waters	Mixed
Contaminants in Snapping Turtle Eggs	4506	Coastal Wetlands	Mixed
Area, Quality & Protection of Alvar Communities	8129 (in part)	Nearshore Terrestrial	Mixed
Sustainable Agricultural Practices	7028	Land Use	Mixed
E. coli and Fecal Coliform in Recreational Waters	4081	Human Health	Mixed
Air Quality	4176	Human Health	Mixed
Economic Prosperity	7043	Societal	Mixed
Acid Rain	9000	Unbounded	Mixed
Native Unionid Mussels	68	Nearshore & Open Waters	Mixed, deteriorating
Scud (Diporeia hoyi)	93	Nearshore & Open Waters	Mixed, deteriorating
Amphibian Diversity & Abundance	4504	Coastal Wetlands	Mixed, deteriorating
Wetland-dependent Bird Diversity & Abundance	4507	Coastal Wetlands	Mixed, deteriorating
Coastal Wetland Area by Type	4510	Coastal Wetlands	Mixed, deteriorating
Effect of Water Level Fluctuations	4861	Coastal Wetlands	Mixed, deteriorating
Extent of Hardened Shoreline	8131	Nearshore Terrestrial	Mixed, deteriorating
DELT in Nearshore Fish	101	Nearshore & Open Waters	Poor (Lake Erie)
Exotic Species Introduced into the Great Lakes (aquatic only)	9002	Unbounded	Poor
Population Monitoring & Contaminants Affecting the American Otter	8147	Nearshore Terrestrial	Insufficient data to assess indicator
Phytoplankton Populations	109	Nearshore & Open Waters	Unable to assess status until targets are determined
Zooplankton Populations	116	Nearshore & Open Waters	Unable to assess status until targets are determined
Urban Density	7000	Land Use	Unable to assess status until targets are determined
Mass Transportation	7012	Land Use	Unable to assess status until targets are determined
Water Use	7056	Societal	Unable to assess status until targets are determined

*See page 25 for definitions

Implications for Managers

This report presents a subjective assessment, based on best professional judgment, of 33 of 80 indicators of ecosystem health. One of the objectives for using indicators to assess the status and trends of Great Lakes ecosystem components is "... to strengthen the decision-making and environmental management concerning the Great Lakes." The material presented in this report leads to certain inevitable implications for environmental and natural resource managers. These implications can be grouped into two major categories: those that relate to the development and use of indicators and those that relate to management of the Great Lakes basin ecosystem.

Indicator Development and Use

Indicator Development and Testing. Many of the indicators presented in this report were not fully implemented, and many more were not presented because they have not been sufficiently developed and tested. To provide an assessment of the Great Lakes based on all the indicators that are necessary and sufficient, further work on the indicators will be required.

Setting Endpoints. Many of the indicators do not have an associated endpoint, target or reference value that establishes when the designation "good" can be applied to the ecosystem component being assessed. Some can be determined through planning exercises such as LaMPs and RAPs, but for others, specific research may be needed. Until such endpoints are provided, however, assessing an indicator will still be useful as it will show trends (i.e. is the condition getting better, worse or staying the same).

Monitoring, Data Collection. Without consistent monitoring or other data collection techniques directed to the suite of Great Lakes indicators, an assessment of the state of the Great Lakes basin ecosystem health will be incomplete. This issue is fundamental to measuring progress toward the goals of the Great Lakes Water Quality Agreement. Consistency in monitoring programs is important in geographic scope, timing and methods.

Data Quality. The quality of data collected and reported is important in order to influence environmental management decisions. Poor quality data can lead to erroneous conclusions about the environment and result in wasted or ill-advised managerial actions.

Information Management, Databases. Because multiple jurisdictions are involved in monitoring and data collection in the Great Lakes basin, the data are scattered widely. As the suite of indicators becomes more fully implemented, the effort required to assemble, analyze and summarize all the data may become a challenge. A deliberate system of information management for Great Lakes indicator data will facilitate rapid and accurate distribution of indicator information to environmental managers, decision makers, and other interested people.

Commitments and Ownership. For state of the Great Lakes reporting to be sustainable, commitments are required for agencies to accept lead roles to collect and interpret data and report on selected indicators prior to each State of the Lakes Ecosystem Conference (SOLEC). Data for some indicators are distributed amongst several agencies. Some agencies have accepted responsibility for preparing biennial indicator reports, and some are considering to which indicators they can commit and to which they can contribute. Many of the indicators still await "adoption," however.

Environmental Management and Programs

Non-native Species Control. In addition to causing severe disruptions to the food web, the introduction and establishment of many non-native species into the Great Lakes basin has severe negative economic consequences. Decreased spending for sport fishing and other recreational opportunities, increased costs to industry for infrastructure, and altered management plans can be anticipated as non-native species displace native ones. Non-native species control is a priority issue. Implementation and maintenance of effective control programs will reduce the risk of further invasions.

Source Controls: Point, Non-point, Agriculture, Atmospheric Emissions.

Continuing loadings of contaminants and nutrients remain a problem in many areas of the Great Lakes. Sources may be point or non-point, and they may involve industrial, agricultural, municipal or other sectors of the economy. In all cases, diligence toward controlling all the sources will facilitate progress toward the goals of the Water Quality Agreement.

Drinking Water. Although the Great Lakes themselves are a good source of treatable drinking water, diligence must be taken to ensure proper treatment, and to minimize the possibility of contaminants entering the distribution system. In addition, consideration of the quality of other sources of water within the basin must be examined (i.e. river and ground water).

Infrastructure, Maintenance. Much progress has been made to reduce the quantity of contaminants and nutrients entering the Great Lakes, in part through the construction and maintenance of sewage treatment facilities, industrial processes to reduce waste, and other physical solutions. This infrastructure requires maintenance to continue efficient, effective operations.

Technology Development. Some Great Lakes problems continue to be unresolved in part because of inadequate technology, e.g., complete remediation of in-place contaminated sediments and zero discharge of toxic chemicals within the Great Lakes

basin. Aggressive pursuit of new devices, systems and/or methodologies will hasten progress toward the virtual elimination of toxic substances in the Great Lakes basin ecosystem.

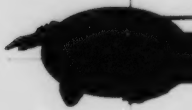
Restoration, Protection Programs. The overall goal of the Great Lakes Water Quality Agreement is to *"restore and maintain the chemical, physical, and biological integrity of the waters of the Great Lakes Basin."* Administrative programs such as ecological preserves, zoning restrictions, parks, wildlife refuges, etc., help to maintain natural features. The application of such controls toward wetlands and terrestrial features is important for the restoration and maintenance of Great Lakes ecosystem components.

Human Population Impacts. Human populations greatly influence and modify the Great Lakes basin ecosystem. Although the problems observed in the Great Lakes can be traced to human origins, particular attention to societal pressures such as urban sprawl, energy consumption and climate change may help to reduce potentially adverse impacts.

Emerging Issues. Not all issues and concerns about the Great Lakes have been anticipated in the Great Lakes Water Quality Agreement and other planning documents. Diligence in monitoring and timely communication of findings will help ensure that government agencies and other organizations identify emerging issues quickly so that environmental management activities can be implemented. New issues may be chemical (e.g., endocrine disrupting chemicals), biological (e.g., disappearance of *Diporeia* from many lake areas), or physical (e.g., effects of water level controls).

Environmental Research. The best managerial activities are based on the best understanding of the structure and functioning of the ecosystem being addressed. Fundamental research into ecosystem processes and the impacts of new or continued stresses will assist environmental managers to best allocate resources toward resolution of identified problems. Similarly, environmental management objectives will help direct basic research toward an understanding of critical ecosystem processes.

Climate Change. Climate change scenarios have been developed for the Great Lakes basin. Projected climate changes will impact both ecological and economic systems. For instance, the possibility of lower water levels will have an impact on coastal wetlands, aquatic habitat and the shipping industry. A potentially warmer and drier climate will impact agriculture, the recreation industry (skiing) and the migration of species northward. Management plans need to be developed with these scenarios in mind.



Section 1

Introduction

The State of the Lakes Ecosystem Conference, or SOLEC, has its roots in the Great Lakes Water Quality Agreement, and its overall purpose:

"... to restore and maintain the chemical, physical, and biological integrity of the waters of the Great Lakes Basin Ecosystem."

The revisions to the Agreement in 1987 established what are now well known concepts and programs such as Beneficial Use Impairments, Remedial Action Plans for Areas of Concern, and Lakewide Management Plans.

Also in the Agreement, however, is the commitment by the two Parties for regular reporting on progress toward several of the general and specific objectives. The State of the Lakes Ecosystem Conferences were established by the governments of Canada and the United States in 1992 in response to those reporting requirements. The conferences were to provide independent, science-based reporting on the state of health of the Great Lakes basin ecosystem every two years.

Four objectives were established for the conferences:

- *To assess the state of the Great Lakes ecosystem based on accepted indicators.* SOLEC facilitates a rational, disciplined approach toward assessing the various components of the Great Lakes ecosystem and reporting the findings.
- *To strengthen decision-making and environmental management concerning the Great Lakes.* SOLEC specifically seeks to provide information and interpretations that are useful to those who make decisions or who influence environmental management practices, whether they are in government, industry, environmental groups or private practice.
- *To inform local decision-makers of Great Lakes environmental issues.* This objective emphasizes the importance of participation by local government and organizations.
- *To provide a forum for communication and networking amongst all the Great Lakes stakeholders.* Great Lakes stakeholders include representatives from federal governments, state and provincial governments, local governments, First Nations and native American Tribes, non-government environmental organizations, industry, academia, and private citizens.

SOLEC has provided an opportunity to look at the "big picture", by starting to integrate science issues. Air, land, water, biota, economics, and human health have been examined in a broad context, with linkages between and amongst these issues being drawn. SOLEC provides information on the state of the Lakes and the stresses on the Lakes to decision-makers in the basin. There is no other forum for this type of scientific debate.

The first SOLEC, 1994, provided a basic assessment of the state of the Great Lakes. This was an overview of the Great Lakes ecosystem, including human health and socio-economics. In 1996, SOLEC evaluated the nearshore environment and some land use issues, introducing the concept of Biodiversity Investment Areas. Both SOLECs assessed the health of the system using only ad hoc indicators and expert opinion.

In 1996, the Parties agreed that a basin-wide, systematic framework using science-based indicators was essential for reporting on ecosystem health. The Parties took this as a challenge for SOLEC 98.



At SOLEC 98, the Parties advanced the development of easily understood indicators which objectively represented the condition of the Great Lakes basin ecosystem, the stresses on the ecosystem, and the human responses to those stresses. These indicators would measure both the health of the system, and progress toward remedying existing problems. A suite of 80 ecosystem health indicators was presented for discussion, with the intention that this suite form the basis of reporting on the state of the Great Lakes. The complete suite and details on the process of indicator selection is in the *Selection of Indicators for Great Lakes Basin Ecosystem Health, Version 4*.

This present report on the State of the Great Lakes is the first report which applies the accepted suite of indicators, starting with 33 indicator assessments. The report is not comprehensive in terms of all 80 indicators. Some of these indicators will require agencies to collect additional data. Others need analysis and synthesis of data from non-traditional sources, such as municipalities, private sector and volunteer organizations. Some indicators need further development through research before they can be used for routine reporting.

This report also presents the condition of each of the Great Lakes and connecting channels as a whole. A general assessment has been made for Lakes Superior, Huron and Erie, and for the St. Clair - Detroit River corridor. The status of the fishery is presented for Lakes Michigan and Ontario, and the issue of biodiversity and non-native species are explored for the St. Lawrence River.

Another major thrust for SOLEC has been the development of the Biodiversity Investment Area (BIA) concept. This concept was first proposed in 1996 in the Nearshore Terrestrial paper for SOLEC 96, and subsequently included in the 1997 State of the Great Lakes report. In this present document, we provide a status report on the integration of nearshore terrestrial, coastal wetland and aquatic BIAs. The full text of the BIA report can be found on the SOLEC website.

Section 2

Lakes Assessment

St. Lawrence River

State of Biodiversity and Aquatic Non-Native Species

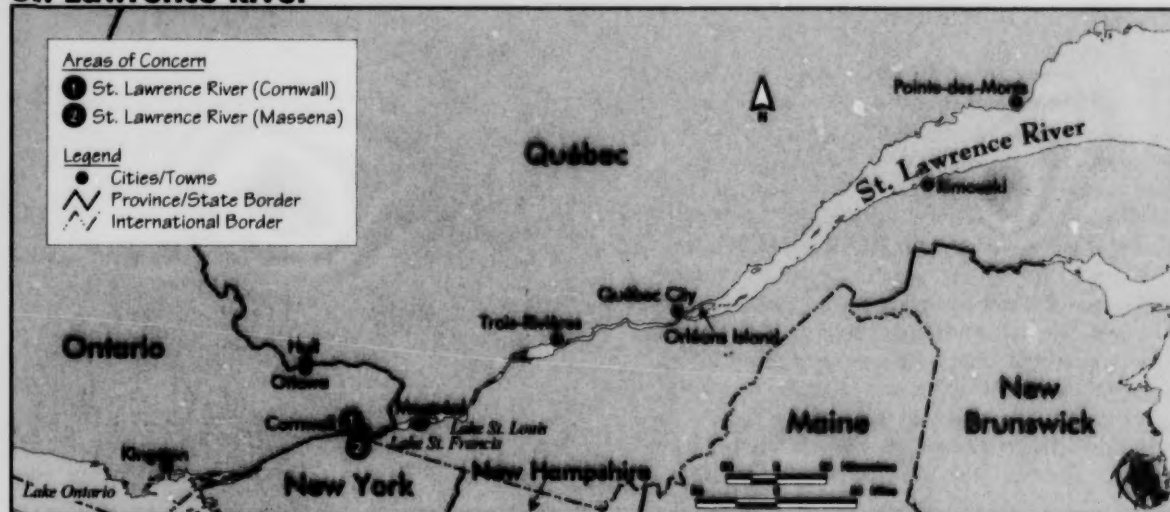
The status of biodiversity in the St. Lawrence River is **mixed-deteriorating** because of continued habitat loss and the introduction of aquatic non-native species.

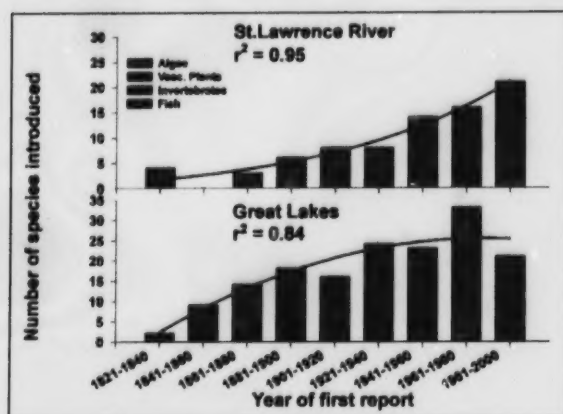
The recently released Biodiversity Portrait of the St. Lawrence River (<http://www.qc.ec.gc.ca/fauna/biodiver/>) has emphasized the loss of wetlands as one of the major factors affecting the integrity of the River ecosystem. The amplitude of annual water level fluctuations has decreased following the opening of the St. Lawrence Seaway, reducing the diversity of wetland flora and affecting fish populations that depend upon flooded wetlands for spawning. Approximately 50% of the St. Lawrence River

shoreline has been modified by agriculture and urbanization. Erosion is a concern along 25% of the shoreline. The result is the loss of both terrestrial and aquatic natural habitats. For example, more than 1,500 hectares of island habitats have been lost since 1950. Still more important losses are predicted if River flows decline because of climate change.

Although habitat loss is having an impact on the St. Lawrence freshwater fish community, aquatic non-native species introductions to the River may be a more serious threat. To aid in developing a conservation strategy for the St. Lawrence River ecosystem, aquatic non-native species introductions are now being studied by Environment Canada. A list of introduced aquatic species is being compiled, the transfer of species between the Great Lakes and the River is being evaluated, and the spatial distribution and temporal trend of introduced species is being assessed using available literature and databases.

St. Lawrence River





Trends in species introductions since 1820.

Source: St. Lawrence Centre-Environment Canada

Recent information indicates a continuing upward trend in aquatic non-native species introductions to the St. Lawrence River with an average rate of one species per year. Approximately 50% of the aquatic non-native species introduced to the Great Lakes have been reported in the St. Lawrence River. Upstream transfer of species from the River to the Lakes is also a source of species introductions to the Great Lakes. However, the problem of non-native species introductions to the St. Lawrence River is due primarily to downstream transfer from the Great Lakes. The percent of species transferred has increased with time, and is expected to remain high over the next decade considering that close to half the species introduced in the Great Lakes have not yet reached the River.

The conclusions regarding biodiversity and aquatic non-native species in the St. Lawrence River are that:

- Despite important habitat losses and modifications, further losses are anticipated as a result of climatic changes that will certainly affect the biodiversity of the River;
- There are insufficient data to assess or predict the potential impact of non-native species in the river;
- The information on aquatic non-native species presence and their distribution need to be validated;
- Guidelines for ship ballast exchange should be rigorously applied and compliance should be enforced for the St. Lawrence River; and
- Overall, the biodiversity of the St. Lawrence River is under considerable stress.

St. Lawrence River Statistics

Elevation	Kingston 246 ft. 75 m Lake St. Francis 151 ft. 46 m Lake St. Louis 66 ft. 20 m Montreal 18 ft. 5.5 m
Length	miles 599 kilometers 964 ^a
Mean Annual Discharge	ft. ³ /s 44,965 m ³ /s 12,600 ^b
Land Drainage Area	sq. mi. 78,090 km ² 204,842 ^c
Water Surface Area	sq. mi. 6,593 km ² 17,077 ^d
Shoreline Length	North Shore 305 mi. 490 km South Shore 280 mi. 450 km
Transient Time	hours (minimum) 100 ^e
Outlet	Gulf of St. Lawrence

^a Length of 964 km is from Kingston to Pointe-des-Monts

^b The mean annual discharge of 12,600 m³/s is at Quebec City Level

^c The land drainage area of 204,842 km² represents the freshwater section in the Quebec Region (Cornwall to Orleans Island)

^d Total water surface from Cornwall to Pointe-des-Monts

^e The transient time applies to Quebec and does not include New York State and Ontario

Source: The River at a Glance, Environment Canada - Quebec Region

Lake Ontario

State of Lake Trout

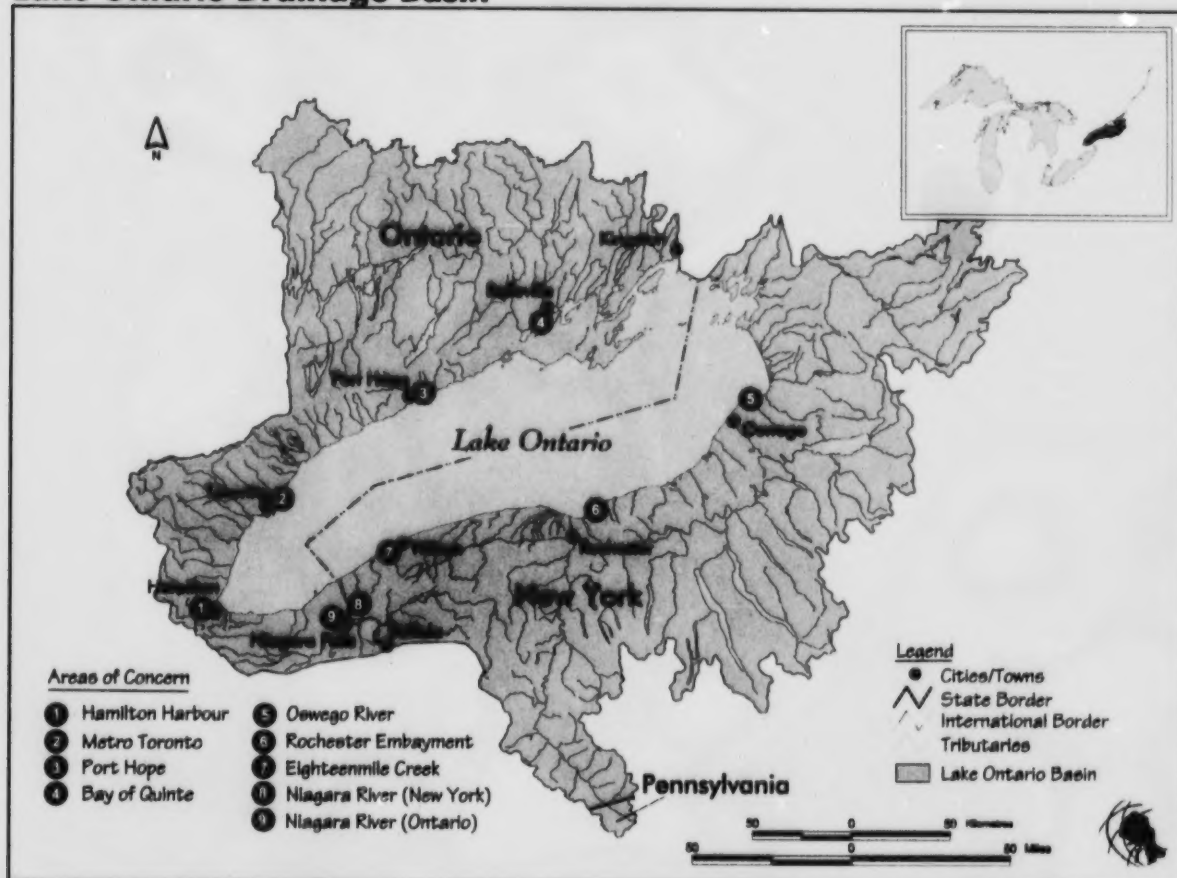
The status of Lake Ontario lake trout is mixed because of recent increases in wild young-of-the-year juveniles, but also because of decreased survival of stocked lake trout, no increase in wild fish abundance, a diet consisting mostly of alewives, and early mortality syndrome.

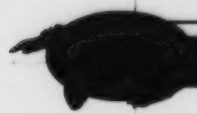
Lake trout is native to all five lakes. It is a top predator that requires oligotrophic (low nutrient levels) conditions and clean spawning substrate. It has a long life span, is genetically diverse, and integrates many ecosystem components. The dominant dietary item is the alewife. The paradox is

that the alewives prey on lake trout fry and are probably linked with Early Mortality Syndrome. The Syndrome is caused by thiamine (vitamin B1) deficiency. The management dilemma is that the prey species that supports an economically valuable fishery inhibits the survival of lake trout and other native species.

Native lake trout have been extirpated (eliminated) from all of the Great Lakes except Superior. Four stressors contributed to the extirpation: over-fishing as early as the nineteenth century; habitat loss from development and agriculture; non-native invasive species such as the sea lamprey; and, contamination of fish by dioxin-like chemicals beginning in the 1930s and peaking in the late 1960s. Contamination levels may have been high enough for 100% mortality of

Lake Ontario Drainage Basin

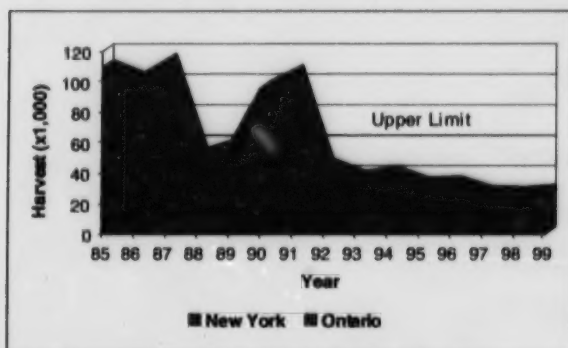




young fish (fry) from 1945 to 1975. After 1991, levels were below the threshold for adverse effects.

Fishery management agencies for Lake Ontario have established a goal of rehabilitating the lake trout population such that, "The adult spawning stock(s) encompasses several year classes, sustains itself at a relatively stable level by natural reproduction, and produces a usable annual surplus (harvest)."

On the positive side, natural reproduction of lake trout has occurred in Lake Ontario since 1985. The proportion of older fish has increased since 1994, while the average age of mature females has been increasing. Fishing mortality remains low. The distribution of naturally produced fish has been widespread throughout the lake, and recent information from the U.S. side of Lake Ontario indicates that numbers of wild lake trout young-of-the-year increased in the spring of 2001. The sea lamprey control program has been effective and lamprey are under control.



Lake trout sport harvest, Lake Ontario.

Source: New York State Department of Environmental Conservation, and Ontario Ministry of Natural Resources

On the negative side, there is decreased survival of stocked lake trout, there has been no increase in total numbers of wild fish, lake trout diet consists mostly of alewives, and early mortality syndrome is still a problem.

The keys to the future success of lake trout rehabilitation in Lake Ontario include improved survival of stocked lake trout; diversification of diet; continued effective sea lamprey control; habitat

protection; restrictive angling regulations; and continued low contaminant levels.

Beyond lake trout rehabilitation work, the Lakewide Management Plan for Lake Ontario proposes three categories of ecosystem indicators: 1) critical pollutant indicators including open water, young-of-the-year fish, herring gull eggs, and lake trout; 2) lower food web biological indicators including nutrients, zooplankton, and preyfish; and, 3) upper food web biological indicators including herring gull, lake trout, mink and otter, and bald eagle.

Lake Ontario Statistics

Elevation^a	
feet	243
metres	74
Length	
miles	193
kilometers	311
Breadth	
miles	53
kilometers	85
Average Depth^a	
feet	283
metres	86
Maximum Depth^a	
feet	802
metres	244
Volume^a	
cu. mi.	393
km ³	1,640
Water Area	
sq. mi.	7,340
km ²	18,960
Land Drainage Area^a	
sq. mi.	24,720
km ²	64,030
Total Area	
sq. mi.	32,060
km ²	82,990
Shoreline Length^a	
miles	712
kilometers	1,146
Retention Time	
years	6
Population:	
USA (1990) [†]	2,704,284
Canada (1991)	5,446,611
Totals	8,150,895
Outlet	St. Lawrence River

^a measured at low water datum

^b Lake Ontario includes the Niagara River

^c including islands

[†] 1990-1991 population census data were collected on different watershed boundaries and are not directly comparable to previous years

Source: The Great Lakes: An Environmental Atlas and Resource Book

Lake Erie

A Changing Ecosystem

The status of Lake Erie is *mixed to mixed-deteriorating* because of continued aquatic non-native species impacts, habitat loss or alteration, and contamination by toxic chemicals.

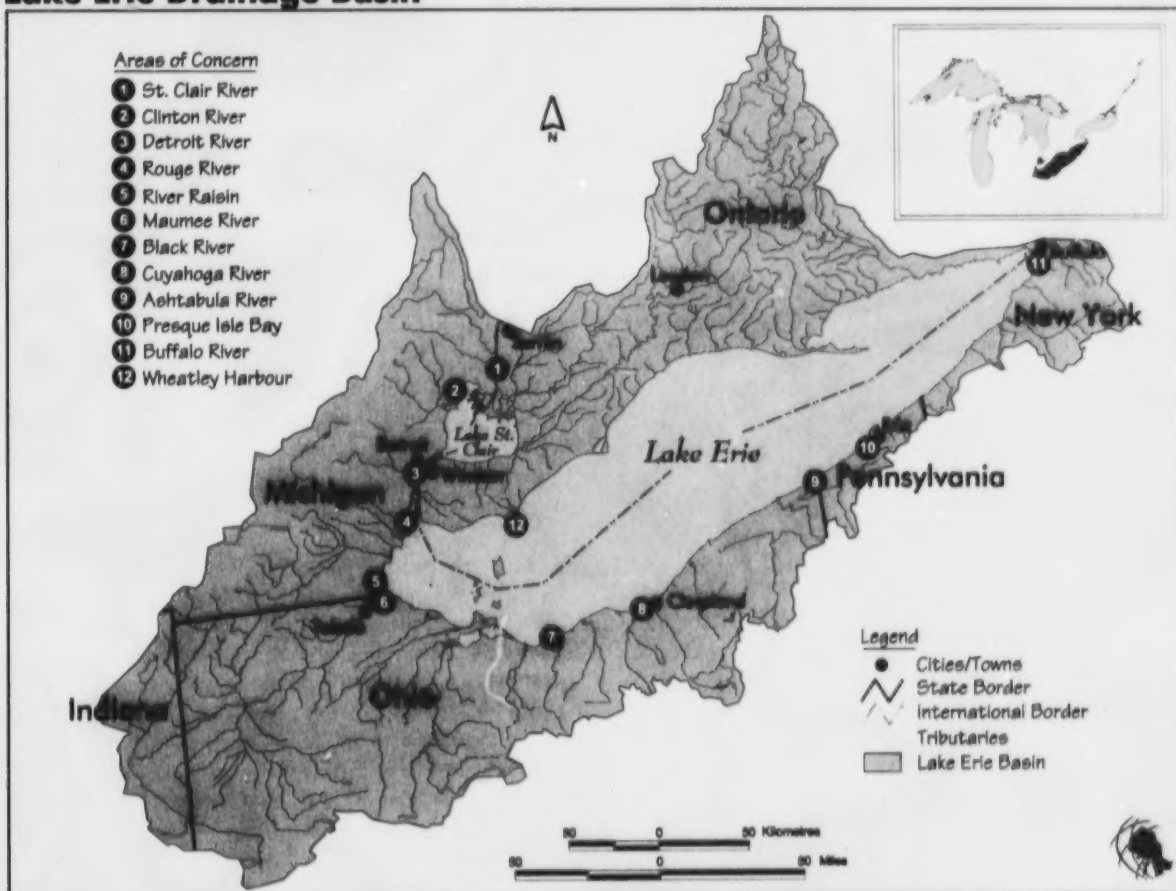
One-third of the human population of the Great Lakes basin lives in the intensively urbanized and agricultural Lake Erie watershed. In addition to providing drinking water for 11 million people, Lake Erie is used for many purposes, including industrial, recreational, municipal and agricultural. Issues and

concerns affecting the health of the Lake Erie ecosystem include continued contamination of fish and wildlife by toxic chemicals, increasing nutrient levels, an influx of aquatic non-native species, and continued habitat loss.

Contaminants

The chemicals of concern include toxic substances (PCBs, chlordane, DDT and metabolites, dioxins, dieldrin, PAHs, agricultural pesticides, endocrine disruptors), heavy metals (lead, mercury), and nutrients (phosphorus, nitrates). For example, although PCBs in Lake Erie sediments decreased from 1971 to 1995, there are still high concentrations in the Western Basin despite contaminant reductions.

Lake Erie Drainage Basin



Lake Erie Statistics

Elevation*	
feet	569
metres	173
Length	
miles	241
kilometers	388
Breadth	
miles	57
kilometers	92
Average Depth*	
feet	62
metres	12
Maximum Depth*	
feet	210
metres	64
Volume*	
cu. mi.	116
km ³	484
Water Area	
sq. mi.	9,910
km ²	25,700
Land Drainage Area*	
sq. mi.	30,140
km ²	78,000
Total Area	
sq. mi.	40,050
km ²	103,700
Shoreline Length*	
miles	871
kilometers	1,402
Retention Time	
years	2.6
Population:	
USA (1990)†	10,017,530
Canada (1991)	1,664,639
Totals	11,682,169
Outlet	Niagara River Welland Canal

* measured at low water datum

* Lake Erie includes the St. Clair-Detroit system

* including islands

† 1990-1991 population census data were collected on different watershed boundaries and are not directly comparable to previous years

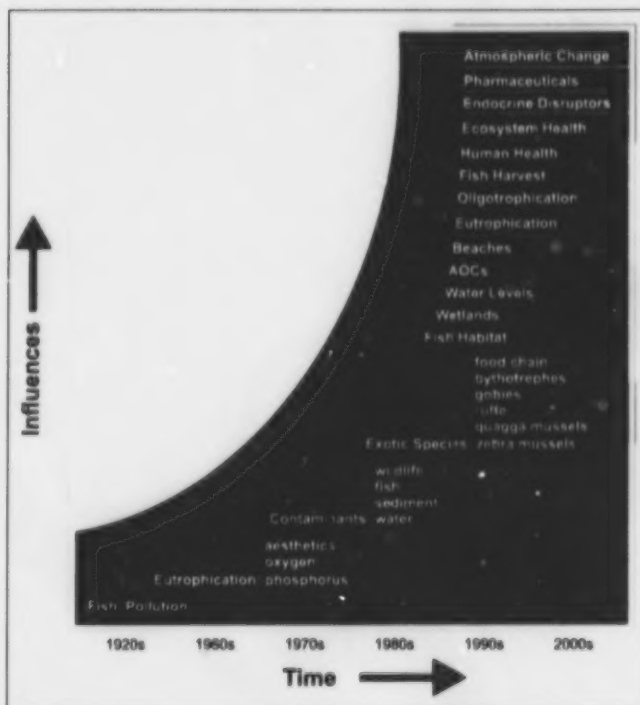
Source: The Great Lakes: An Environmental Atlas and Resource Book

Nutrients
Although significant reductions in the annual loadings of phosphorus to Lake Erie has been achieved since the early 1970s, concentrations of phosphorus in the Western and Central Basins still regularly exceed the target levels derived from the Great Lakes Water Quality Agreement. In addition, the concentration of nitrates in the Eastern and Western Basins has increased since the early 1980s, possibly affecting amphibians and reptiles.

Non-native Species

Aquatic non-native species such as zebra mussels, the round

goby, purple loosestrife, and the fishhook water flea (*Cercopagis*) are continuing to disrupt the food web. Zebra mussel grazing in particular appears to be altering community structure. The abundance of phytoplankton in the Eastern Basin is less than predicted from phosphorus concentrations in the water, and *Microcystis* (a type of blue green alga) blooms have appeared in the Western Basin. Populations of large, cold water species of zooplankton have been reduced, and zebra mussel



Influences on the Lake Erie ecosystem through time.

Source: Environment Canada

larvae and the spiny waterflea (*Bythotrephes*) are replacing native zooplankton populations.

Fisheries

Walleye and yellow perch populations are declining, while lake whitefish harvest is increasing.

Habitat

Lake Erie basin natural habitats are continuing to degrade, including wetlands, forests, sand beaches, dunes and barrens, lakeplain prairies, as well as tributaries and the open lake. Emerging issues such as climate change will add to existing problems as will continued human population growth.

The ability to monitor and track changes in the Lake Erie ecosystem has been diminished because ecosystem changes are occurring rapidly, and because resources for monitoring are declining. Research is needed to understand changes in the ecosystem.

St. Clair River - Lake St. Clair - Detroit River Corridor

The status of the St. Clair River - Lake St. Clair - Detroit River Corridor is *mixed* because of fish consumption advisories, historical and current wetland losses, a degraded benthos, contaminated sediments, exceedances in water quality standards, beach closures, and problems with drinking water; but contaminants are generally below problem levels and there have been incremental gains in habitat protection and restoration.

The corridor consists of the St. Clair and Detroit Rivers, and Lake St. Clair. The major population centres are Port Huron, Michigan; Sarnia, Ontario;

Detroit, Michigan; and Windsor, Ontario. The population centres are also industrial centres. The Michigan side of the corridor is largely populated, with wetland areas remaining on the north side of Lake St. Clair. The Ontario side is agricultural. Walpole Island, which is First Nations territory, has superb tallgrass prairie, wetland, and oak savanna habitats.

Lake St. Clair was surrounded primarily by wetlands prior to European settlement, and although these wetlands are considerably smaller today, Lake St. Clair is still habitat for a diverse fishery. Recreational boating and fishing are of great economic importance in the region. There are currently about 200 marinas and 150,000 boats in Michigan alone, with an annual value to the economy of approximately \$260 million. More than 1.5 million fish are taken from Lake St. Clair annually, accounting for nearly half of the entire Great Lakes sport fishing industry.

The issues or problems that indicate the health of the Corridor is degraded are: fish consumption advisories, historical and current wetland losses, a degraded benthos, contaminated sediments, exceedances of water quality standards and guidelines, beach closures, and problems with drinking water.

In the St. Clair River, lead and chloride levels have decreased. Phosphorus levels increased in the mid-1990s but are now leveling off. Levels of copper are constant, but zinc levels have been rising.

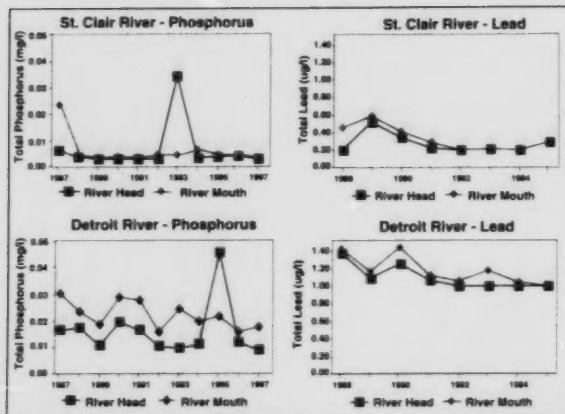
In Lake St. Clair, chloride levels are constant. Mercury levels in the edible portion of walleye have decreased significantly, PCB levels increased in 2000 after a steady decline. HCB and OCS levels in channel catfish have declined.

In the Detroit River, lead has decreased, while chloride has increased slightly at the head of the river. Levels of copper and zinc are constant.

Historic coastal wetland losses in the Corridor were severe. However, since the early 1980s, the total area of protected and restored wetlands has increased. In the last two

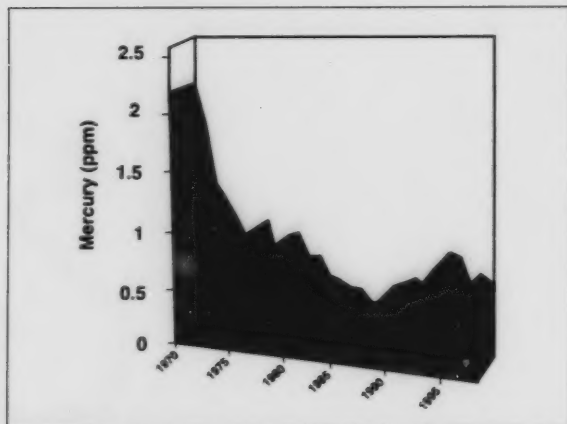
The St. Clair - Detroit Corridor





Comparison of phosphorus and lead levels at St. Clair and Detroit Rivers.

Source: Ontario Ministry of Environment and Environment Canada



Mercury levels in Lake St. Clair walleye.

Source: Environment Canada

decades, more than 500 hectares in the St. Clair River, 3000 hectares in Lake St. Clair, and 500 hectares in the Detroit River have been protected or restored.

Spills to the St. Clair and Detroit Rivers have decreased considerably since 1986. Water quality has shown a marked improvement.

Loss of fish and wildlife habitat is a primary and consistent concern throughout the Corridor. Current activities to mitigate habitat loss are:

- Critical habitat acquisition;

- Shoreline enhancement;
- Development of a biodiversity conservation strategy and atlas;
- Identification of candidate sites for protection and rehabilitation; and
- Protection of designated wetlands.

In conclusion, the Corridor is important ecologically and commercially.

Current needs are:

- Effective source controls for current contamination and better management of historical contamination;
- Focus on habitat protection and restoration with a view toward incremental gains; and
- Ongoing monitoring to ensure continuous improvement.

Lake St. Clair Statistics

Elevation	
feet	569
metres	173
Length	
miles	26
kilometres	42
Mean Breadth	
miles	24
kilometres	39
Mean Depth	
feet	11
metres	3.4
Mean Annual Discharge	
ft. ³ /s	183,000 ^a
m ³ /s	5,182 ^a
Maximum Depth (natural)	
feet	21
metres	6.5
Watershed Area	
sq. mi.	460
km ²	1,191
Land Drainage Area	
sq. mi.	6,100 ^b
km ²	5,799 ^b
Water Surface Area	
sq. mi.	400 ^c
km ²	1,036 ^c
Shoreline Length	
miles	62
kilometres	100

^a Inflow into Lake St. Clair

^b Land areas include the total drainage area to the outlet of the upstream lake

^c Water Surface Area does not include area of connecting channels

Source: Lake St. Clair: Its Current State and Future Prospects, Lake St. Clair Network, United States Geological Survey

Lake Huron

The Lake in the Middle

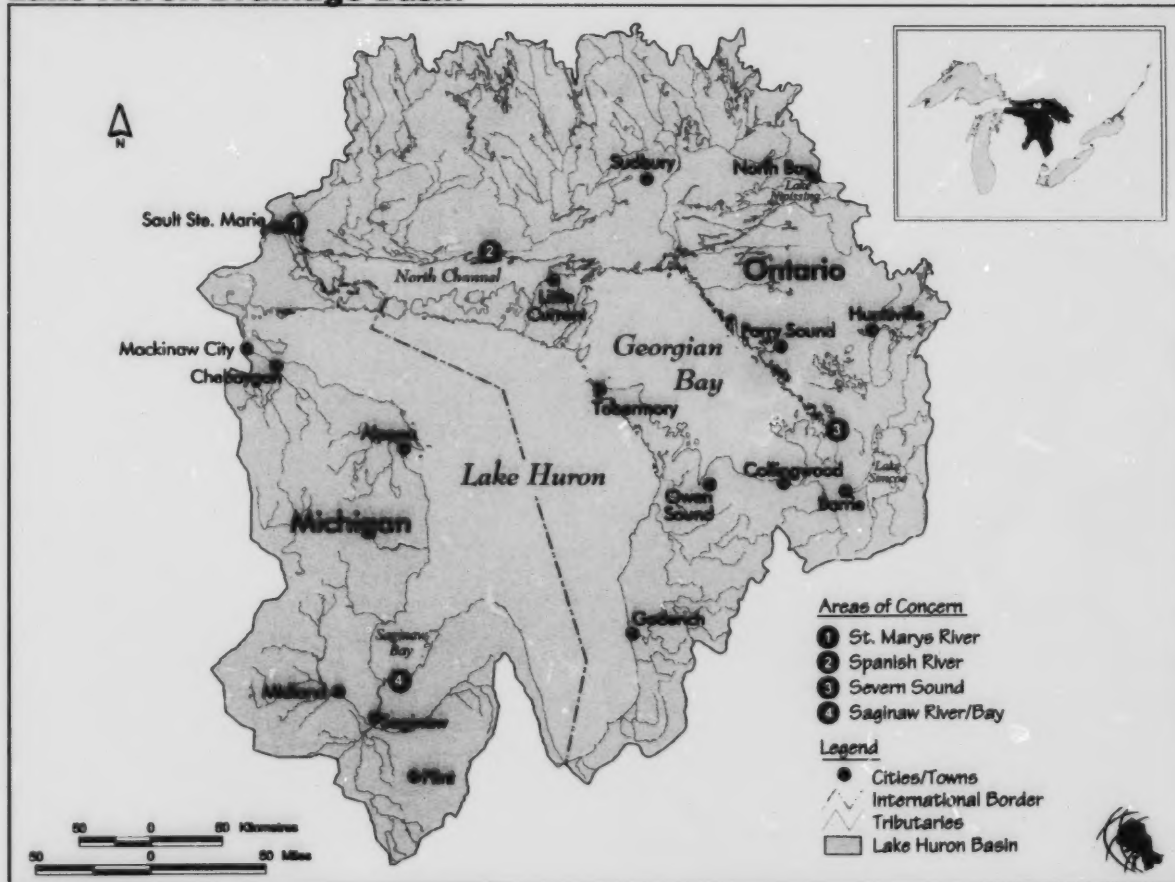
The status of Lake Huron is *mixed* because, despite gains in terms of point source controls and progress in Areas of Concern, there are still stresses attributed to large atmospheric inputs of contaminants; hardened shorelines; and continued threats from non-native species.

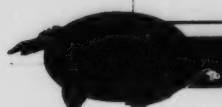
Lake Huron is often called "the lake in the middle" due to its position in the Great Lakes and the view that the level of pollution is somewhere between "pristine" Lake Superior and Lake Ontario. In spite of its "middle" status, Lake Huron is interesting and unique. Lake Huron has over 30,000 islands, more than any other lake in the world. The largest,

Manitoulin, is the largest island in a freshwater lake. If the shorelines of the islands are included, Lake Huron has the longest lakeshore of any lake in the world as well. More than 2.5 million people live in the basin, mostly in the southern portion. Historical pollution discharges, particularly in Sarnia, Ontario and Saginaw Bay, Michigan, have caused serious problems in a number of areas in the basin, including the designation of five Areas of Concern. The five Areas are the St. Marys River, Spanish River, Saginaw River and Bay, Severn Sound, and the St. Clair River. Current activities, including industry and seasonal land use development, are putting increasing pressures on wildlife habitats and unique ecosystems.

Critical pollutants have been identified and include PCBs, chlordane, dioxins, mercury,

Lake Huron Drainage Basin





Lake Huron Statistics

Elevation*	
feet	577
metres	176
Length	
miles	206
kilometers	332
Breadth	
miles	183
kilometers	245
Average Depth*	
feet	195
metres	59
Maximum Depth*	
feet	750
metres	229
Volume*	
cu. mi.	850
km ³	3,540
Water Area	
sq. mi.	23,000
km ²	59,600
Land Drainage Area*	
sq. mi.	51,700
km ²	134,100
Total Area	
sq. mi.	74,700
km ²	193,700
Shoreline Length*	
miles	3,827
kilometres	6,157
Retention Time	
years	22
Population:	
USA (1990)†	1,502,687
Canada (1991)	1,191,467
Totals	2,694,154
Outlet	St. Clair River

* measured at low water datum

* land drainage area for Lake Huron includes St. Marys River

* including islands

† 1990-1991 population census data were collected on different watershed boundaries and are not directly comparable to previous years

Source: The Great Lakes: An Environmental Atlas and Resource Book

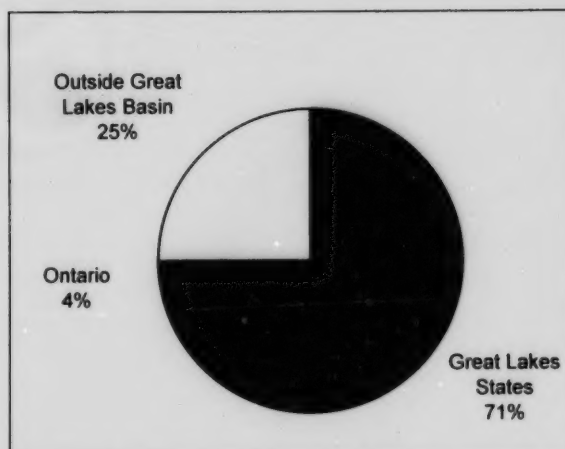
sediment/suspended solids, and DDT.

Concentrations of PCBs in whole lake trout have declined significantly since 1978, but are still above the protection values for fish-eating birds and mammals. There has been no significant decline in PCBs or mercury since the mid-1980s.

Continuing sources may include historical discharges and air deposition. The rate of decrease for contaminant trends in fish eating birds has slowed. Most bird populations have become re-established, but some reproductive problems persist. Bald eagle populations continue to grow, with interior breeding areas having greater productivity than nearshore ones. Loadings from water sources are the lowest of the Great

Lakes, but air sources are the highest. About 80%-90% of dioxins are from atmospheric sources. Contaminated sediments in the Areas of Concern and out-of-basin atmospheric deposition must be addressed to deal with critical pollutant issues.

Nearshore terrestrial ecosystems still sustain a great diversity of wildlife. They sustain important habitats as food sources for fish and wildlife. Saginaw Bay continues to provide essential habitat,



Sources of atmospheric deposition of dioxin to Lake Huron, 1999.

Source: Great Lakes Trends: Into the New Millennium, Office of the Great Lakes, Michigan Department of Environmental Quality

but a continued loss of wetlands is a serious threat. Critical stresses include degradation and loss of historical tributary and nearshore habitats, the introduction of non-native species, over-fishing, and fish and wildlife reproductive failure.

The Lake Huron fisheries goals are:

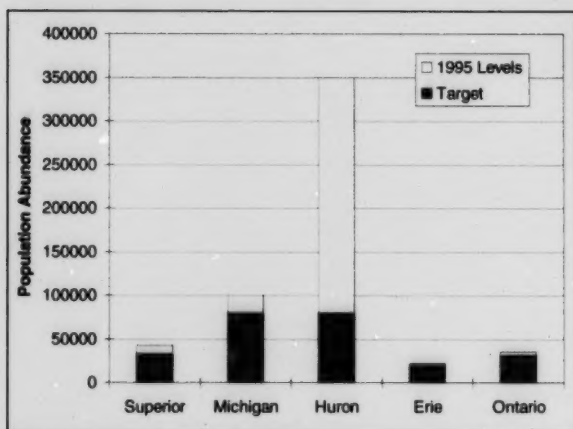
- to protect and enhance existing habitats and rehabilitate degraded habitats;
- to achieve no net loss of the productive capacity of habitats;
- to restore damaged habitats; and
- to support the reduction of contaminants.

However, there are several fishery concerns such as the dependence on hatchery production, the impact of non-native species on fish communities, and the insufficient rate of lake trout reproduction, as well as those concerns discussed in the following paragraphs.

One fishery concern is that historically, tributaries were important sources of cool, high quality water serving as spawning and nursery habitat. The construction of dams has excluded fish from many tributaries. This is a deterrent to achieving balanced fish communities because tributaries are now inadequate habitat for all life cycle stages. Dams now fragment many streams where historical spawning occurred.

A second fishery concern is nearshore habitat. Many nearshore areas have been altered with shoreline protection structures. In many areas, the band of transition vegetation has disappeared. The cumulative impact of these structures is significant and increasing in regard to the fishery.

A third concern is the loss of coastal wetlands. Most current coastal wetland losses have been around small urban centres on the lakeshore. Losses are due to agriculture, cottage development, road construction, dredging, and channelization.

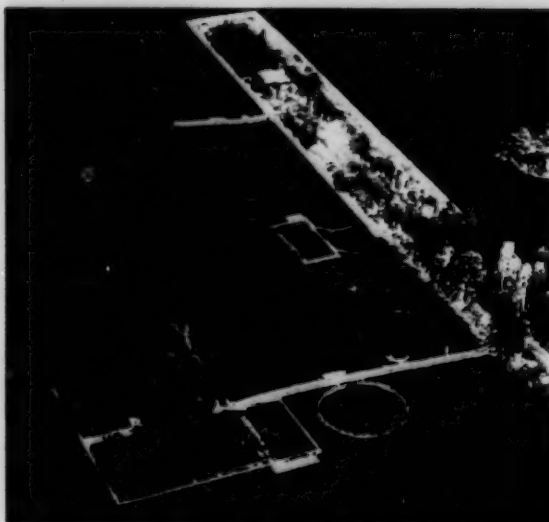


Sea lamprey populations and targets.

Source: Great Lakes Fishery Commission

A fourth fishery concern is the significant stress to aquatic communities caused by non-native species. Species that are having a great impact are the sea lamprey, zebra mussel, ruffe, round goby, and purple loosestrife. The sea lamprey problem is associated with production in the St. Marys River and is the most severe impediment to a healthy fish community. Cost effective sea lamprey control on the river may be within reach. The sea lamprey population is expected to be reduced by 85% by 2010.

Finally, aquaculture is a growing fishery concern. Fish farms now account for over 60% of rainbow trout production in the Ontario waters of Lake Huron.



Aquaculture pens near Parry Sound, Georgian Bay.

Source: Ontario Ministry of Natural Resources

The following actions are still needed to improve the Lake Huron ecosystem:

- Control atmospheric inputs of persistent toxic substances;
- Initiate an aquatic nuisance species control program beyond the sea lamprey control program;
- Continue progress in Areas of Concern;
- Implement watershed management plans;
- Fully fund the lamprey control program;
- Encourage local protection and restoration efforts;
- Research lower trophic levels; and
- Control pathogen sources (Saginaw Bay and southeast Lake Huron).

Lake Michigan State of the Fishery

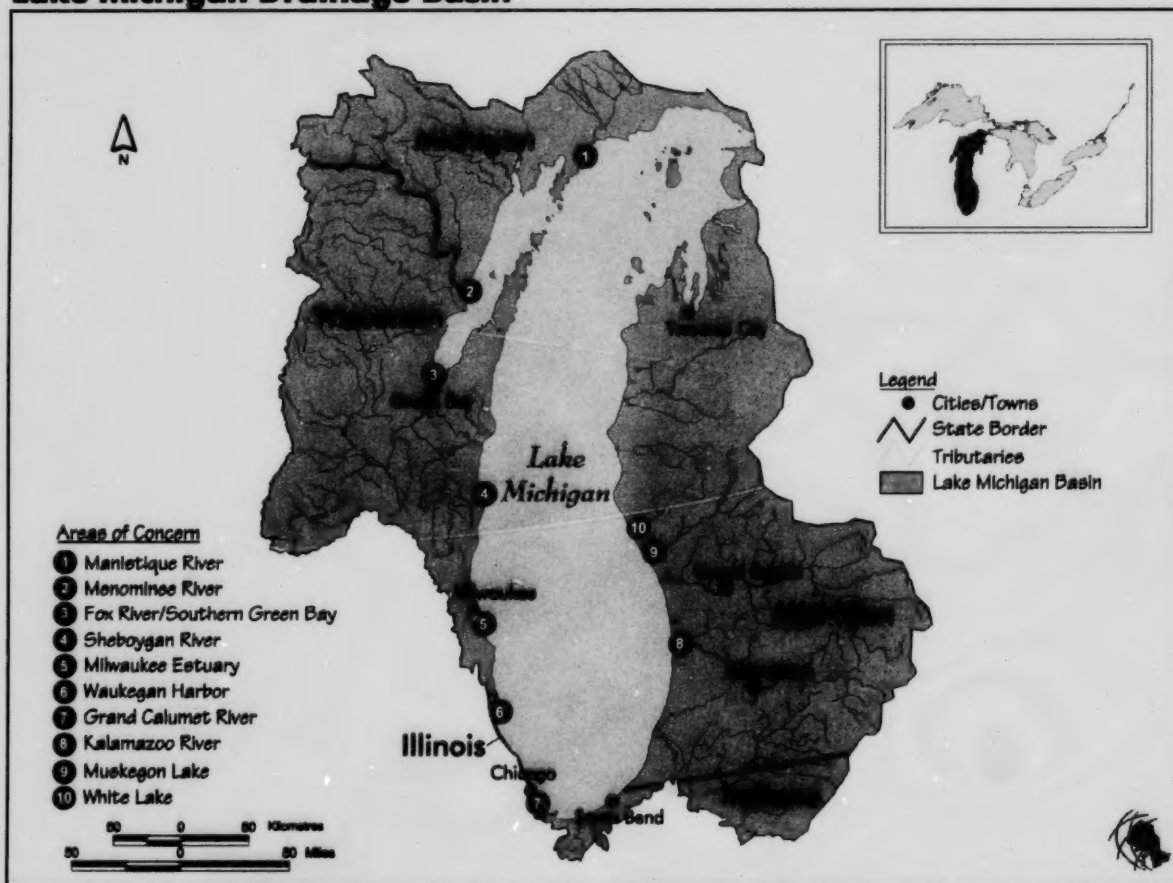
The status of Lake Michigan is **mixed** because of continued impairments and only slight improvement towards the goals established by the Lakewide Management Plan. The status of progress toward achieving Lake Michigan fish community objectives is as follows: fish population structures—mixed/improving; restoration or protection of fish habitat—mixed/deteriorating; prevention or control of aquatic nuisance species—mixed.

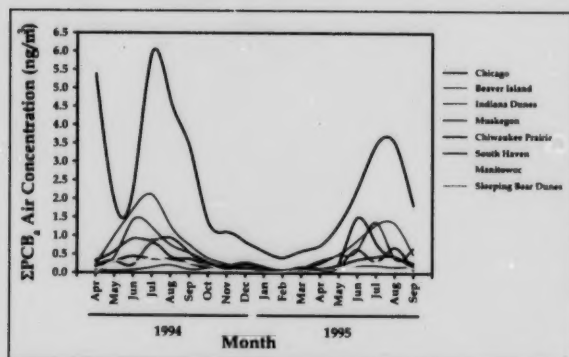
Lake Michigan is an outstanding natural resource of global significance, but it is under stress and in need

of special attention. It is the second largest lake by volume and has the world's largest collection of freshwater sand dunes. It has approximately 40% of all the Great Lakes coastal wetlands and more than 26% of the prime waterfowl. It also has ten Areas of Concern in various stages of cleanup.

The sources of continuing contamination to the lake include atmospheric deposition, tributaries, and historic sediment deposition. The southern-most end of the lake has the highest concentrations of PCBs, with the PCB loadings for the lake primarily from the atmosphere at 1536 kilograms (3386 pounds) per year. Atmospheric mercury and atrazine loadings, in large part deposited by rain and snow, are 729 and 1694 kilograms per year respectively (1607 and 3735

Lake Michigan Drainage Basin





Atmospheric concentration of PCB over Lake Michigan.

Source: U.S. Environmental Protection Agency, Great Lakes National Program Office

pounds respectively). PCB loadings (1994 data) from major monitored tributaries are greatest from the Fox River, Grand Calumet Harbor, and Kalamazoo River. According to 1995 data, atrazine loadings are greatest from the Fox, St. Joseph, Pere Marquette, and Kalamazoo Rivers. Mercury loadings (1995 data) are greatest from the Fox, Grand, Kalamazoo, and St. Joseph Rivers.

The fish community goal for Lake Michigan is to restore and maintain the biological integrity of the fish community so that production of desirable fish is sustainable and ecologically efficient. For preyfish species, the objective is to maintain a diversity of preyfish species at population levels matched to primary production and to predator demands. Expectations are for a lakewide preyfish biomass of 0.5 to 0.8 billion kilograms (1.2 to 1.7 billion pounds). However the abundance of benthos (bottom organisms) at 40 sites in Lake Michigan's southern basin has shown a decline in bottom life, likely linked to the introduction of zebra mussels. The dominant species, *Diporeia*, is eaten by a variety of Great Lakes fish and is an important component of the Lake Michigan food web. Another component of the forage base, bloater chub, alewife, and rainbow smelt has also declined since the early 1990s.

For salmon and lake trout, the objective is to establish a diverse harvest of 2.7 to 6.8 million kilograms (6 to 15 million pounds) of which 20-25% is lake trout. Another objective is to establish self-

sustaining lake trout populations. Lakewide trout and salmon harvests have dropped since the mid-1980s.

For bottom feeders, the objective is to maintain self-sustaining stocks of lake whitefish, round whitefish, sturgeon, suckers, and burbot. The expected annual yield of lake whitefish alone should be 1.8 - 2.7 million kilograms (4 to 6 million pounds), but for 1999, the lakewide harvest of all these fish was about 3.2 million kilograms (7 million pounds).

The goal of inshore fish stocks is to maintain self-sustaining stocks of yellow perch, walleye, smallmouth bass, pike, catfish, and panfish. Expected annual yields should be 0.9 to 1.8 million kilograms (2 to 4 million pounds) for yellow perch and 0.1 to 0.2 million kilograms (0.2 to 0.4 million pounds) for walleye. In 1999, the lakewide yellow perch harvest was about 272,000 kilograms (600,000 pounds), a steady decline from the mid to late 1980s. The lakewide walleye harvest was just under 68,000 kilograms (150,000 pounds), or at about the same level since 1985.

Other fish community objectives include protecting and sustaining a diverse community of native species, including other species not specifically mentioned earlier such as gars and bowfin. These

Lake Michigan Statistics

Elevation^a	
feet	577
metres	176
Length	
miles	307
kilometers	494
Breadth	
miles	118
kilometers	190
Average Depth^a	
feet	279
metres	85
Maximum Depth^a	
feet	925
metres	282
Volume^a	
cu. mi.	1,180
km ³	4,920
Water Area	
sq. mi.	22,300
km ²	57,800
Land Drainage Area	
sq. mi.	45,600
km ²	118,000
Total Area	
sq. mi.	67,900
km ²	175,800
Shoreline Length^a	
miles	1,638
kilometres	2,633
Retention Time	
years	99
Population: USA (1990)[†]	10,057,026
Outlet	Straits of Mackinac

^a measured at low water datum

^b including islands

[†] 1990-1991 population census data were collected on different watershed boundaries and are not directly comparable to previous years

Source: The Great Lakes: An Environmental Atlas and Resource Book



species contribute to the biological integrity of the fish community and should be recognized and protected for their ecological significance and cultural and economic values. Another fish community objective is to suppress the sea lamprey to allow the achievement of other fish community objectives.

In conclusion, progress toward achieving fish community objectives is mixed/improving for fish population structures; mixed/deteriorating for the restoration and protection of fish habitat; and mixed for the prevention/control of aquatic nuisance species. To protect and enhance fish habitat and rehabilitate degraded habitats, it will be necessary to achieve a "no net loss" of the productive capacity of habitat supporting Lake Michigan's fish communities. High priority should be given to the restoration and enhancement of historic riverine spawning and nursery areas for anadromous species.

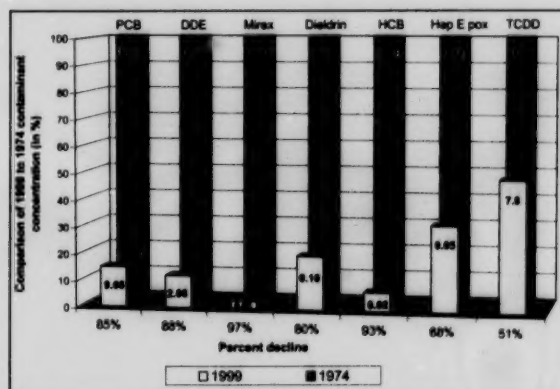
Lake Superior

State of the Ecosystem

The status of the Lake Superior basin ecosystem is mixed because of: poor offshore chub populations; mixed (some gains and some losses) in terms of continued fish consumption advisories, the status of herring gull populations, critical pollutant reductions, atmospheric deposition, human population change, quantity of water consumed; mixed/improving for lake trout nearshore, all habitats for lake herring, sea lamprey abundance; and good for lake trout offshore habitat and lake whitefish nearshore.

Lake Superior's aquatic communities are closest to what the communities of the Great Lakes must have been like prior to European settlement. The status of these aquatic communities is measured by two indicators: fish abundance, including lake trout, chubs, lake herring, and whitefish, and sea lamprey abundance.

The trend in catch for lean and Siscowet lake trout in commercial fisheries from 1950 to 1998 has not changed for lean trout and is upward with fluctuations for Siscowet trout. Catch per unit effort for lake herring is declining while the chub fishery is almost non-existent. Lake whitefish catch per unit effort for both gill net and trap net has risen over the last decades. Sea lamprey has declined since the 1950s with a slight rise in 1999.



Contaminants in herring gull eggs, Lake Superior, 1974 vs. 1999 data.

Source: Environment Canada

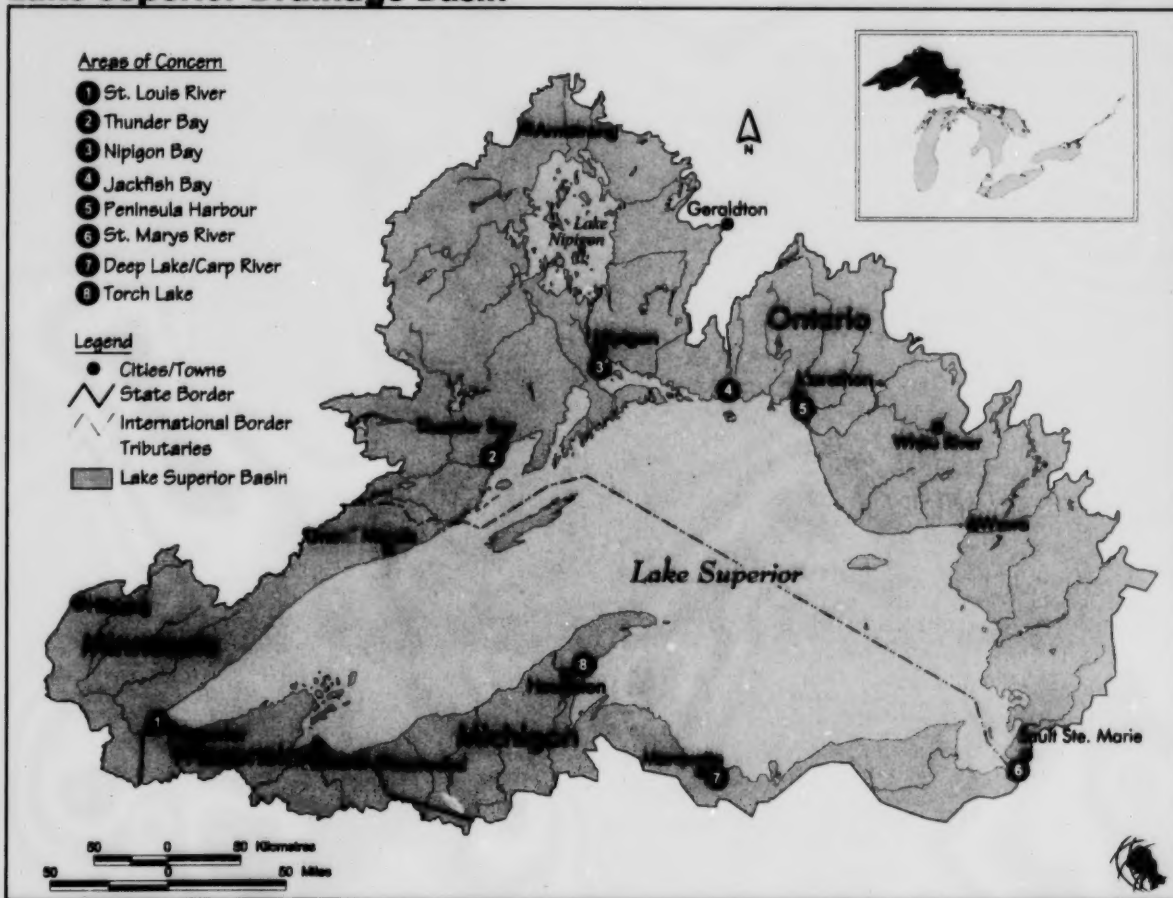
Wildlife community indicators are forest breeding birds, with trends unique to the local environment, and colonial waterbirds, where herring gulls are indicators of regional contaminant levels. Herring gull contaminants—PCBs, DDE, mirex, dieldrin, HCB, heptachlor-epoxide, and TCDD—have declined from 51% to 97% since 1974. Herring gull abundance, measured in number of breeding pairs and number of colonies, has nearly doubled in Canada between 1976 and 1999. In the United States, numbers have increased only slightly, from 7,106 pairs to 7,715 and from 90 colonies to 134.

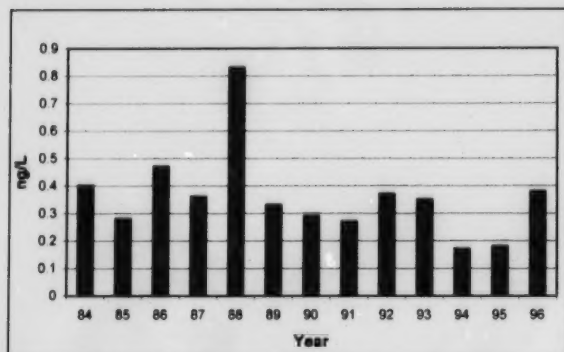
Progress toward the management goal of zero discharge of emissions of nine critical pollutants is mixed. The mercury goal for 2000 has been met. But meeting the 2010 milestones will require strategies

relating to fuel combustion and mining. Mercury emissions from sources in the Lake Superior basin have decreased to about 1,000 kilograms per year. Open lake concentrations of most toxic chemicals are lower than the most sensitive guidelines, except for dieldrin at 0.114 ng/L; PCBs at 0.0705 per ng/L; and toxaphene at 0.9 and 0.7 ng/L. PCBs in Chinook salmon (0.3 ppm) are still well above the unlimited consumption level of 0.05 ppm.

One Lakewide Management Plan objective is the virtual elimination of atmospheric emissions of toxic chemicals of human origin from the lake. Atmospheric deposition is the dominant pathway for critical pollutants. Atmospheric loadings will continue for an unknown length of time.

Lake Superior Drainage Basin





Dieldrin trends in Lake Superior precipitation.

Source: Environment Canada

Indicators of how well humans are being sustained by the landscape are related to use of ecosystem resources, trends in human population density and municipal water use. Data from Ontario show a relatively stable population base and a stable per capita residential water use.

Lake Superior emerging issues are numerous and include: introduction of non-native species, airborne pollutants, human migration into the basin, habitat fragmentation, meeting zero-discharge milestones, exposure and effects of chemical mixtures, endocrine disrupting chemicals, mercury, new chemicals, and domestic use of burn barrels. The Lake Superior Binational Program's initial focus has been on the Zero Discharge Demonstration Program. In 1997, the Program broadened to incorporate six ecosystem themes in its charge. Active public participation was sought through the Binational Forum. Project implementation is underway during 2000 to 2002.

Lake Superior Statistics

Elevation^a	
feet	600
metres	183
Length	
miles	350
kilometers	563
Breadth	
miles	160
kilometers	257
Average Depth^a	
feet	483
metres	147
Maximum Depth^a	
feet	1,332
metres	406
Volume^a	
cu. mi.	2,900
km ³	12,100
Water Area	
sq. mi.	31,700
km ²	82,100
Land Drainage Area	
sq. mi.	49,300
km ²	127,700
Total Area	
sq. mi.	81,000
km ²	209,800
Shoreline Length^a	
miles	2,729
kilometres	4,385
Retention Time	
years	191
Population:	
USA (1990) [†]	425,548
Canada (1991)	181,573
Totals	607,121
Outlet	St. Marys River

^a measured at low water datum

^b including islands

[†] 1990-1991 population census data were collected on different watershed boundaries and are not directly comparable to previous years

Source: The Great Lakes: An Environmental Atlas and Resource Book

Section 3

State of the Great Lakes Based on Indicators

The status of the chemical, physical, and biological integrity of the waters of the Great Lakes basin ecosystem has been assessed and is considered mixed because:

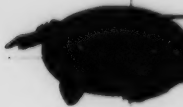
- Surface waters are still amongst the best sources of drinking water in the world;
- Progress has been made both in cleaning up contaminants and in rehabilitating some fish and wildlife species;
- Invasive species continue as a significant threat to Great Lakes biological communities;
- Atmospheric deposition of contaminants from distant sources outside the basin confounds efforts to eliminate these substances;
- Urban sprawl threatens high quality natural areas, rare species, farmland and open space; and
- Development, drainage, and pollution are shrinking coastal wetlands.

These conclusions are based on assessments of 33 indicators made by the governments of Canada, United States, Provinces, States, Tribes, and First Nations, including local governments, industry, academia, and non-governmental organizations. The indicators are part of suite of 80 that have been determined to be necessary, sufficient and feasible in order to convey a picture of Great Lakes basin health. Several categories comprise the suite: **open and nearshore waters, coastal wetlands, nearshore terrestrial, land use, human health, societal, and unbounded** (those indicators that transcend the other categories - for example, Acid Rain or indicators of climate change).

The assessment is incomplete. Data for several indicators within this report are uneven (or not basin-wide) across jurisdictions. Of a total of 80 Great Lakes ecosystem indicators, 47 have yet to be reported or require further development. In some cases, the required data have not been collected. Changes to existing monitoring programs or the initiation of new monitoring programs are also needed. Several indicators are under development. More research or testing may be needed before these indicators can be assessed.

This section details the purpose, state, and future pressures for each of the 33 indicators that were analyzed. The authors of the indicator reports were asked to assess, in his or her best professional judgment, the overall status of the ecosystem component in relation to established endpoints or ecosystem objectives, when available. Five broad categories were used:

- **Good.** The state of the ecosystem component is presently meeting ecosystem objectives or otherwise is in acceptable condition.
- **Mixed, Improving.** The ecosystem component displays both good and degraded features, but overall, conditions are improving toward an acceptable state.
- **Mixed.** The state of the ecosystem component has some features that are in good condition and some features that are degraded, perhaps differing between lake basins.
- **Mixed, Deteriorating.** The ecosystem component displays both good and degraded features, but overall, conditions are deteriorating from an acceptable state.



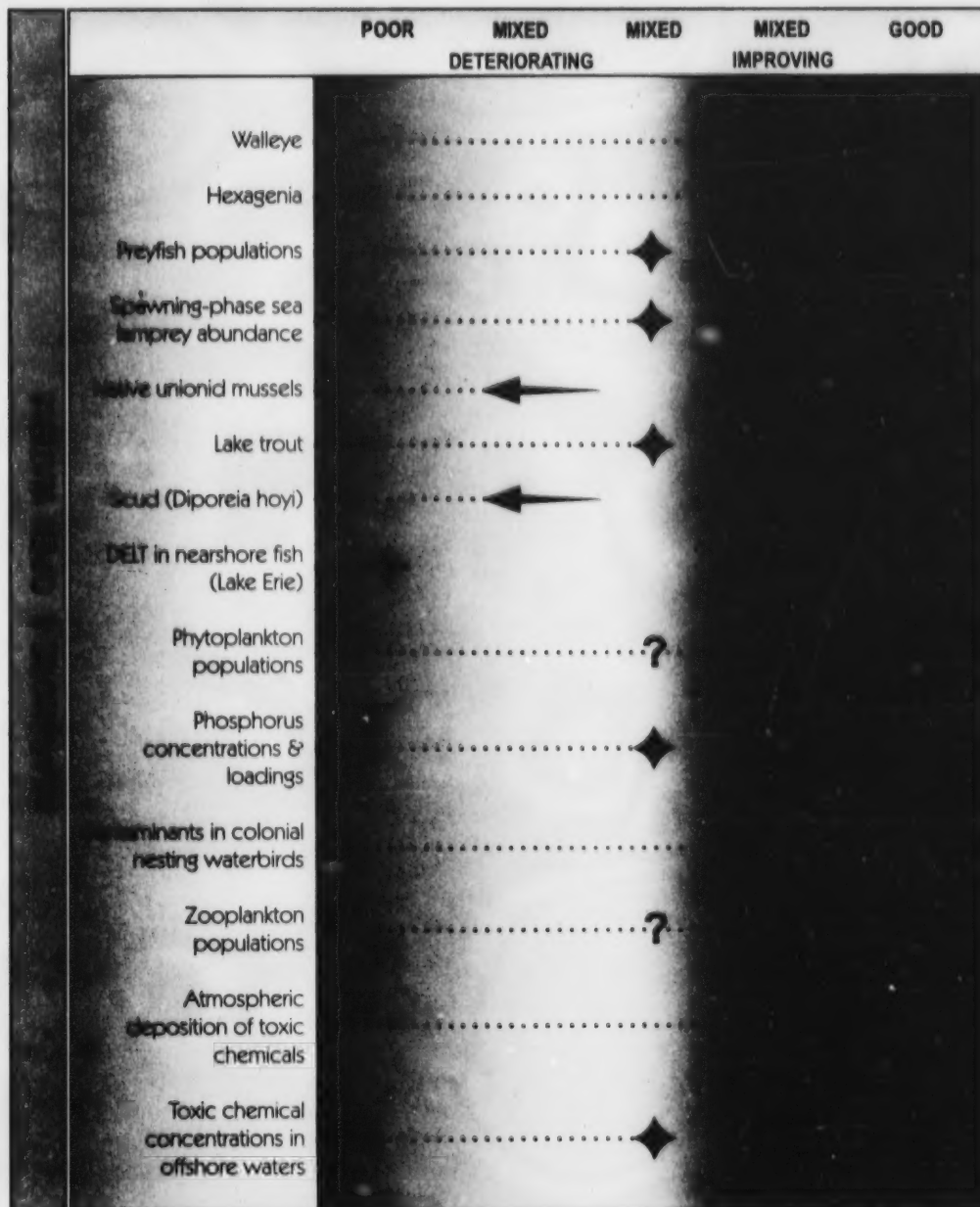
- **Poor.** The ecosystem component is severely negatively impacted and it does not display even minimally acceptable conditions.

Over the next several State of the Lakes Ecosystem Conferences, additional indicators will be developed, monitoring programs will be adjusted, information management systems put into place, and research and testing completed to refine the indicators. A robust suite of indicators will strengthen the biennial assessment of the status of the Great Lakes.

The Great Lakes community is encouraged to assist in this assessment by exploring the detailed indicator summaries and conclusions, and providing feedback on the content, format, conclusions, and implications for management. The complete indicator reports for these 33 indicators can be found in *Implementing Indicators, November 2000*.

3.1 Nearshore & Open Waters

Nearshore and Open Water Indicators - Assessment at a Glance



Walleye

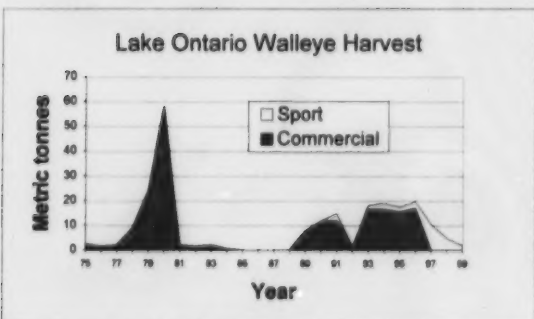
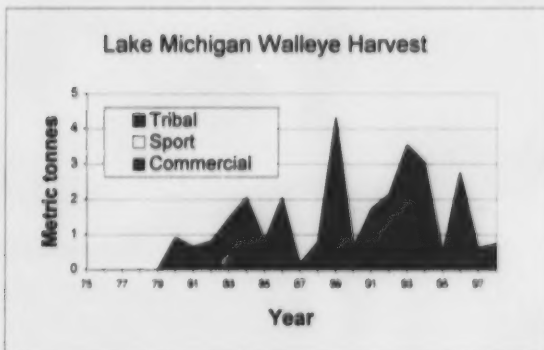
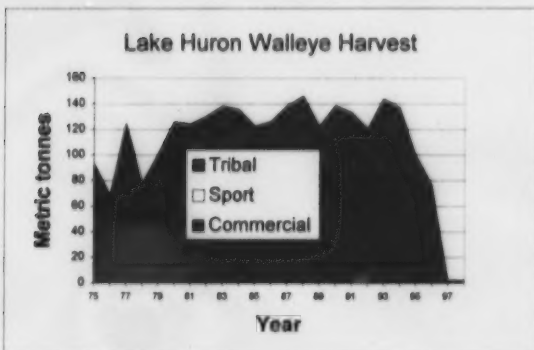
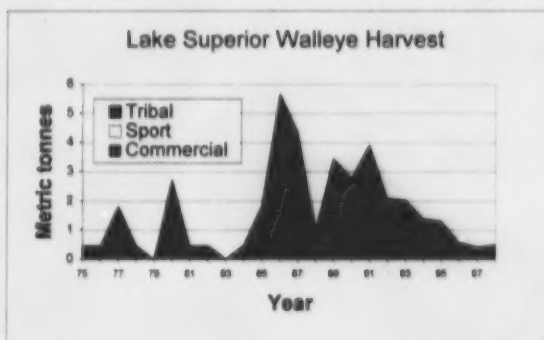
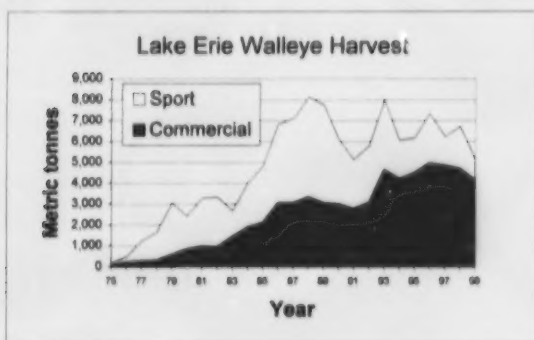
Assessment: Good

Purpose

Trends in the amount of walleye harvested indicate changes in overall fish community structure, the health of percids (the family of fish to which walleye belong), and the stability and resiliency of the Great Lakes aquatic ecosystem.

State of the Ecosystem

In general, walleye yields peaked during periods of environmental conditions that favoured walleye (mid-1980s), and they remain substantially improved from levels of the 1970s. Total yields were highest in Lake Erie, intermediate in Lakes Huron and Ontario, and lowest in Lakes Michigan and Superior, as shown by the historical pattern before the 1930s. Declines in the 1990s were likely related to shifts in environmental states, i.e., reduced nutrient levels in the water, changing fisheries, and, perhaps in Lake



Walleye harvests for each of the Great Lakes.

(Note: Established Fish Community Goals and Objectives are: Lake Huron: 700 metric tonnes, Lake Michigan: 100-200 metric tonnes, Lake Erie: sustainable harvests in all basins. Achievement of these targets will require healthy walleye stocks in each lake.)

Source: Tom Stewart (Lake Ontario-OMNR), Tom Eckhart (Lake Ontario-NYDEC), Dave Fielder (Lake Huron-MDNR), various annual OMNR and ODNR Lake Erie fisheries reports, and the GLFC commercial fishery data base

Erie, a population naturally coming into balance with its prey base.

Future Pressures

Walleye populations will be influenced by loss of habitats; environmental factors that alter water levels, water temperature, water clarity, and flow (currents); climate change impacts; non-native species, like zebra mussels, ruffe, and round gobies; and human disturbance of tributary and nearshore habitats through activities like dredging, diking, farming, and filling of wetlands.

Acknowledgments

Author: Roger Knight, Ohio Department of Natural Resources.

Fishery harvest data were obtained from Tom Stewart (Lake Ontario-OMNR), Tom Eckhart (Lake Ontario-NYDEC), Karen Wright (Upper Lakes tribal data-COTFMA), Dave Fielder (Lake Huron-MDNR), Terry Lychwyck (Green Bay-WDNR), various annual OMNR and ODNR Lake Erie fisheries reports, and the GLFC commercial fishery data base. Gene Emond (ODNR) collated data into a standardized form. Fishery data should not be used for purposes outside of this document without first contacting the agencies that collected them.

Hexagenia

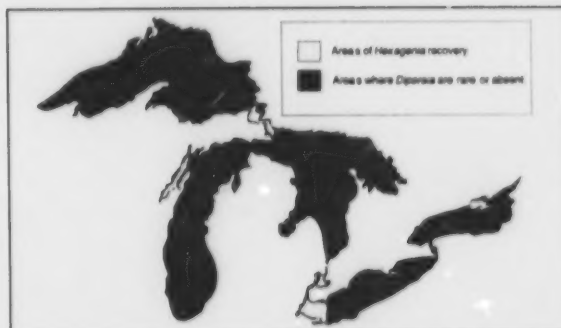
Assessment: Mixed, improving

Purpose

Hexagenia (or burrowing mayfly) is intolerant of pollution and thus reflects the quality of water and lakebed sediments in mesotrophic Great Lakes habitats (moderate nutrient levels). It was historically an important item in the diets of many valuable fishes, and the massive swarms of winged adults that are typical of healthy, productive *Hexagenia* populations are highly visible.

State of the Ecosystem

There is now evidence that *Hexagenia* have begun to recover in Green Bay (Lake Michigan), Saginaw Bay (Lake Huron), and the Western Basin of Lake Erie, and that they have fully recovered in the southwestern part of the Western Basin of Lake Erie. Most of Lake St. Clair and portions of the upper Great Lakes connecting channels support populations of *Hexagenia* with the highest biomass and production measured anywhere in North America. In sharp contrast, *Hexagenia* have been extirpated (eliminated) in polluted portions of these same Great Lakes waters and no recovery is presently evident. The recovery of *Hexagenia* in western Lake Erie is a signal which



Hexagenia recovery and Diporeia decline in the Great Lakes.

Source: Thomas Edsall, U.S. Geological Survey, Biological Resources Division, Ann Arbor, MI, unpublished data. Figure created by Melanie Neilson, Environment Canada

shows clearly that properly implemented pollution controls can bring about the recovery of a major Great Lakes mesotrophic ecosystem.

Future Pressures

Hexagenia are sensitive to periodic occurrences of anoxic (lacking oxygen) bottom waters resulting from excessive nutrient inputs; and toxic pollutants, including oil and heavy metals, which accumulate and persist in the lakebed sediments. Stormwater runoff from impervious surfaces and combined sewer overflows are significant sources of these pollutants.

Acknowledgments

Author: Thomas Edsall, U.S. Geological Survey, Biological Resources Division, Ann Arbor, MI.

Preyfish Populations

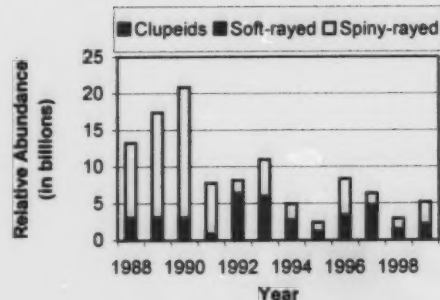
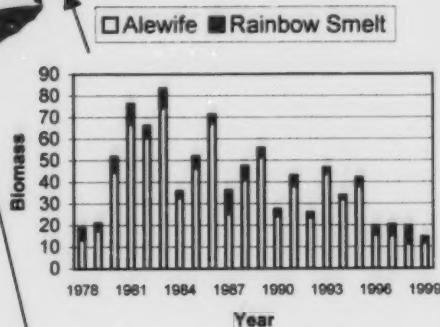
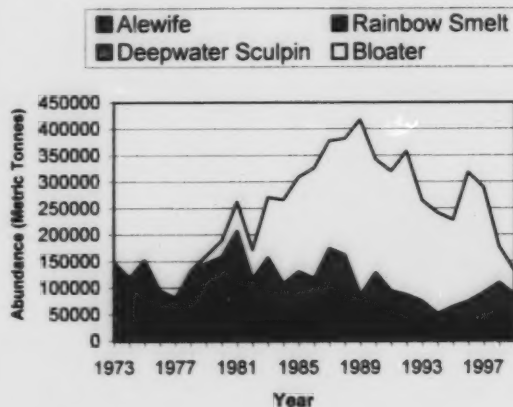
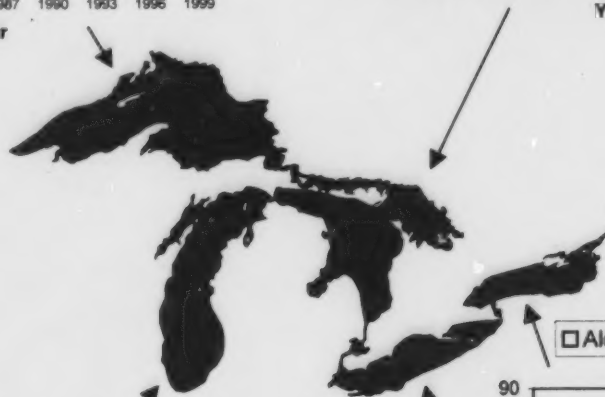
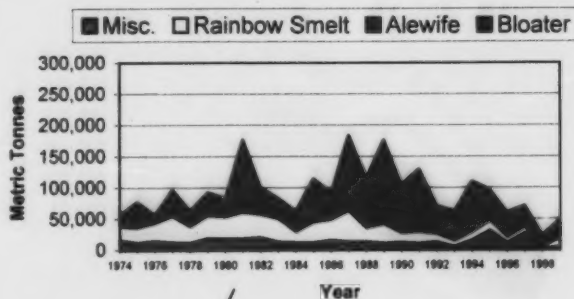
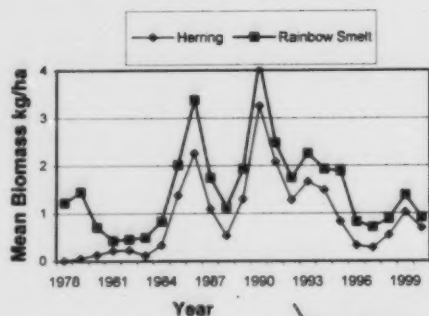
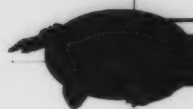
Assessment: Mixed

Purpose

This indicator directly measures the abundance and diversity of preyfish populations, especially in relation to the stability of predator species which are necessary to maintain the biological integrity of each lake.

State of the Ecosystem

Lake Superior. The population of lake herring has declined in recent years, believed to be the result of environmental factors rather than parental stock size. In contrast, rainbow smelt biomass has remained



Preyfish population trends in the Great Lakes.

Source: U.S. Geological Survey Great Lakes Science Center, except Lake Erie, which is from surveys conducted by the Ohio Division of Wildlife

low and is likely controlled by predation from trout and salmon. Sculpins remain at low but consistent levels of abundance.

Lake Michigan. Alewives and smelt remain at lower levels than in previous years, apparently controlled in large part by predation pressure. Bloater biomass continues to decline due to lack of recruitment and slow growth. Sculpins continue to contribute a significant portion of the preyfish biomass.

Lake Huron. The decline in bloater abundance has resulted in an increased proportion of alewives in the preyfish community. Predation pressure may be an important force in both alewife and rainbow smelt populations. Sculpin populations have varied over time, but have been at lower levels in recent years.

Lake Erie. The preyfish community in Lake Erie has a high species diversity, but recently it has shown declining trends in all three basins. In the eastern basin, rainbow smelt (soft-rayed) have shown significant declines in abundance. In the western and central basins, white perch (spiny-rayed) and rainbow smelt have declined. Gizzard shad and alewife (clupeids) abundance has been quite variable across the survey period.

Lake Ontario. Alewives and to a lesser degree rainbow smelt dominate the preyfish population. Alewives had declined to low levels; though this species has exhibited strong 1998 and 1999 year classes (a year class refers to all the fish of a particular species born that year) which have recently increased their abundance. Rainbow smelt show some increase due to influence of 1996 year class, but the scarcity of large individuals indicates heavy predation. Overall, shifts to deeper water have been noted in fish distributions and may be related to establishment of zebra mussels. Sculpin populations have declined and remained at low levels since 1990.

Future Pressures

Preyfish populations are likely to be impacted by predation by salmon and trout, pressures from *Dreissena* (zebra and quagga mussels) populations, and dramatic declines in *Diporeia* (scud) populations.

Acknowledgments

Author: Guy W. Fleischer, U.S. Geological Survey Great Lakes Science Center, Ann Arbor, MI.

Contributions from Robert O'Gorman and Randy W. Owens, U.S. Geological Survey Great Lakes Science Center, Lake Ontario Biological Station, Oswego NY, Charles Madenjian, Gary Curtis, Ray Argyle and Jeff Schaeffer, U.S. Geological Survey Great Lakes Science Center, Ann Arbor, MI, and Charles Bronte and Mike Hoff, U.S. Geological Survey Great Lakes Science Center, Lake Superior Biological Station, Ashland, WI., and Jeffrey Tyson, Ohio Div. of Wildlife Sandusky Fish Research Unit, Sandusky, OH.

All preyfish trend figures are based on annual bottom trawl surveys performed by U.S. Geological Survey Great Lakes Science Center, except Lake Erie, which is from surveys conducted by the Ohio Division of Wildlife.

Spawning-Phase Sea Lamprey Abundance

Assessment: Mixed

Purpose

This indicator estimates the abundance of sea lampreys in the Great Lakes, which has a direct impact on the structure of the fish community and health of the aquatic ecosystem. Populations of large, native, predatory fishes can be diminished by sea lamprey predation.

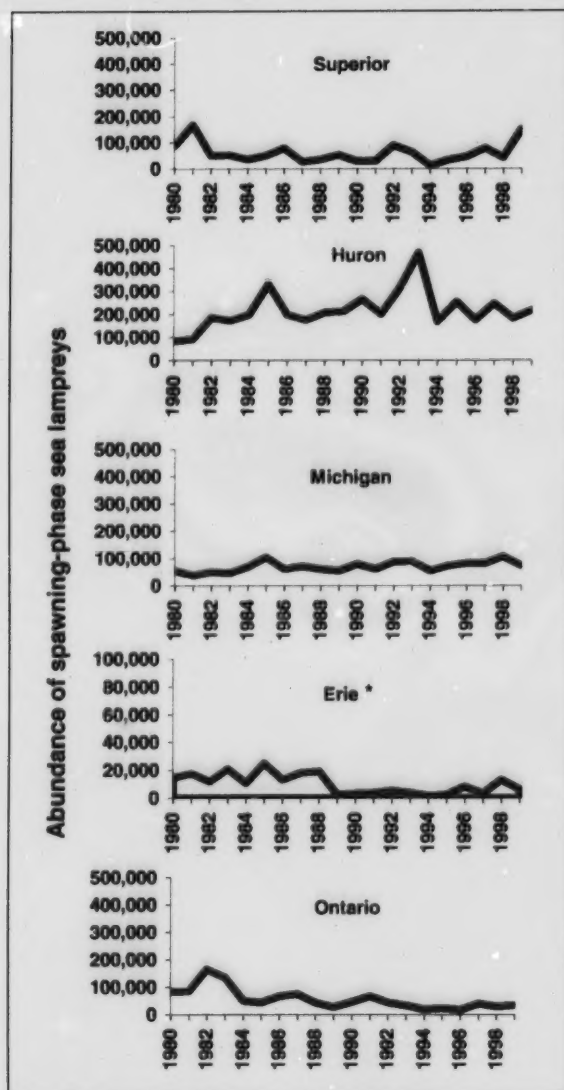
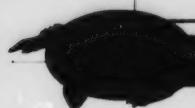
State of the Ecosystem

Lake Superior. During the past 20 years populations have fluctuated but remain at levels less than 10% of peak abundance. Although there is concern that abundance has increased since 1995, survival objectives for lake trout continue to be met.

Lake Michigan. Over most of the lake, populations have been relatively stable. However, an increase in the population in the north is caused by an expansion of the large population in Lake Huron moving into Lake Michigan.

Lake Huron. During the early 1980s, populations increased, particularly in the north. Through the 1990s Lake Huron contained more sea lamprey than all the other lakes combined. Lake trout restoration activities were abandoned in the northern portion of the lake during 1995 because so few lake trout were surviving to maturity because of attacks by sea lamprey. An integrated control strategy was initiated in the St. Marys River in 1997, including targeted application of a new bottom-release lampricide, enhanced trapping of spawning animals, and sterile-male release.

Lake Erie. Lamprey abundance has increased since the early 1990's to levels that threaten the lake trout success. An assessment during 1998 indicated that



Total lakewide abundance of sea lamprey estimated during the spawning migration.
***Note the scale for Lake Erie is 1/5 larger than the other lakes.**

Source: Gavin Christie and Jeffrey Slade, Great Lakes Fishery Commission, Rodney McDonald, Department of Fisheries and Oceans Canada, and Katherine Mullett, U.S. Fish and Wildlife Service

the sources of this increase were several streams in which treatments had been deferred due to low water flows or concerns for non-target organisms.

Lake Ontario. Abundance of spawning-phase sea lampreys has continued to decline to low levels throughout the 1990s.

Future Pressures

As water quality improves in Great Lakes tributaries so does the potential for sea lampreys to colonize new locations. Short lapses in control can result in rapid increases in abundance. Significant additional control efforts, like those on the St. Marys River, may be necessary to maintain suppression.

Acknowledgments

Author: Gavin Christie, Great Lakes Fishery Commission, Ann Arbor, MI.

Native Unionid Mussels

Assessment: Mixed, deteriorating

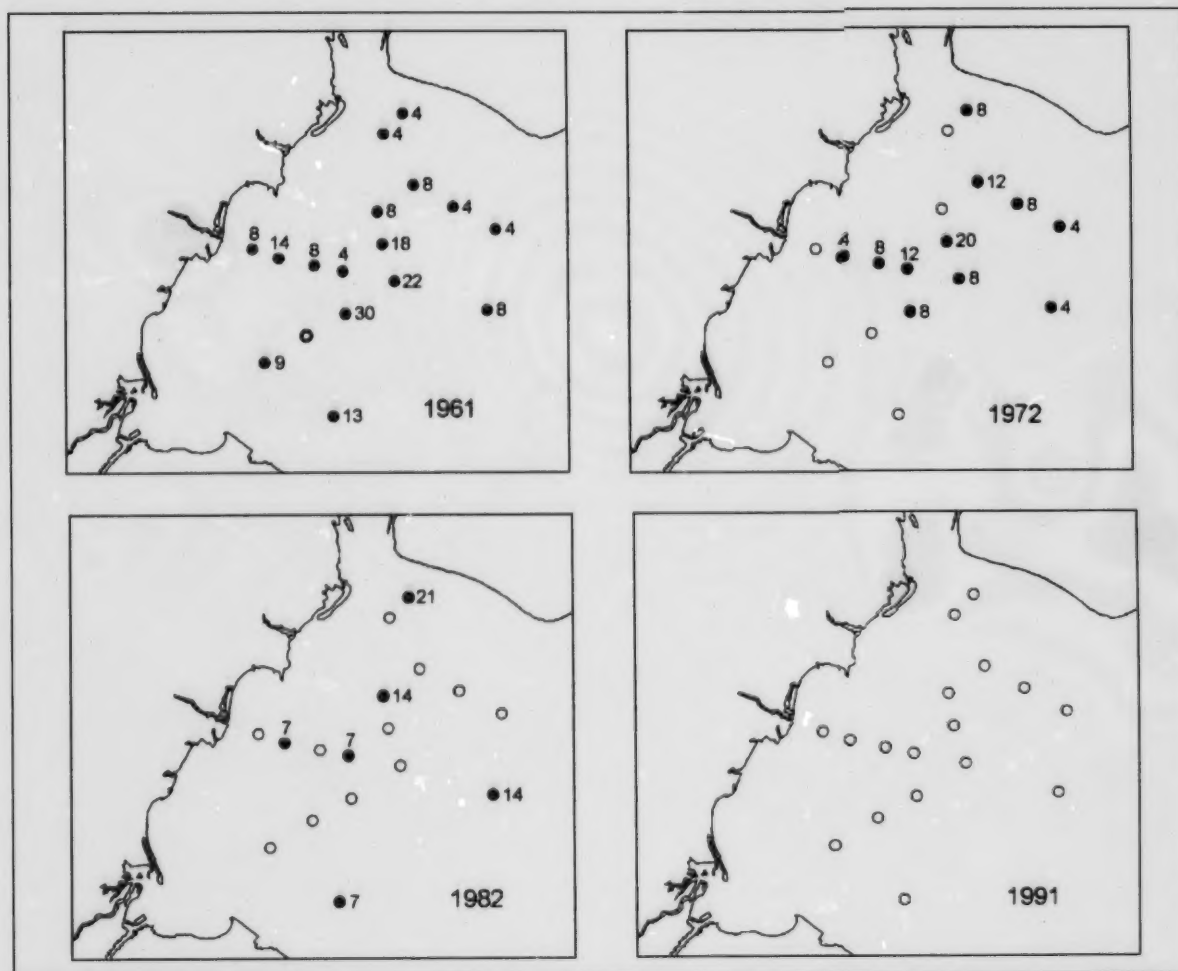
Purpose

Unionid distribution and abundance patterns reflect the general health of the aquatic ecosystem, and in particular those components interacting with the bottom substrates. Unionid mussels are long-lived, relatively sedentary animals, which are highly sensitive to habitat degradation, organic, inorganic, and metal pollutants, and biofouling by zebra mussels.

State of the Ecosystem

Many species of unionid mussels are listed as endangered or threatened. Most unionid populations in the Great Lakes and associated watersheds have declined as a result of decades of habitat alteration such as dredging, urbanization, increased sedimentation, and shoreline armoring. Additional stresses include changes in fish distribution, chemical pollutants in the water column and sediments and the arrival of competitive and predatory non-native species.

Unionid species diversity and density have severely declined in the open waters of Lake Erie, the Detroit River, and Lake St. Clair since the arrival of zebra mussels in the mid-1980s. Many sites do not contain any live unionids. Healthy and diverse



Abundance of freshwater mussels (numbers/m²) collected in 1961, 1972, 1982 and 1991 from 17 sites in the western basin of Lake Erie. Black circles indicate the presence of native unionid mussels and the number indicates the quantity found at the test site. White circles indicate the absence of native unionid mussels.

Source: T. Nalepa, National Oceanic and Atmospheric Administration, B. Manny, J. Roth, S. Mozley, and D. Scholesser

communities, however, were recently discovered in Lake Erie in nearshore areas with firm substrates, in soft sediments associated with coastal marshes, and in a coastal marsh in the St. Clair River delta.

Future Pressures

Pressures on the native unionid mussel populations include: zebra mussel expansion (biofouling); changes to native fish community structure by non-

native species (unionid reproductive cycles contain a parasitic larval stage requiring specific fish hosts); increasing urban sprawl; development of factory farms; and elevated use of herbicides.

Acknowledgments

Authors: S. Jerrine Nichols, U.S. Geological Survey Great Lakes Science Centre, Ann Arbor, MI and Janice Smith, Environment Canada, Burlington, ON.



Lake Trout

Assessment: Mixed

Purpose

This indicator tracks the status and trends in lake trout populations, and it will be used to infer the basic structure of cold water predator and prey communities and the general health of the ecosystem. By the late 1950s, lake trout were extirpated throughout most of the Great Lakes. Full restoration will not be achieved until natural reproduction is re-established and maintained.

State of the Ecosystem

Lake trout abundance dramatically increased in all the Great Lakes shortly after the initiation of sea lamprey control, stocking, and harvest control. Natural reproduction is now widespread in Lake Superior, and stocking has been discontinued throughout most of the lake. Densities of wild fish have exceeded that of hatchery-reared fish since the mid 1980s. Unfortunately natural reproduction is at very low levels or non-existent in the rest of the Great Lakes, therefore populations in these waters are maintained solely by stocking.

Future Pressures

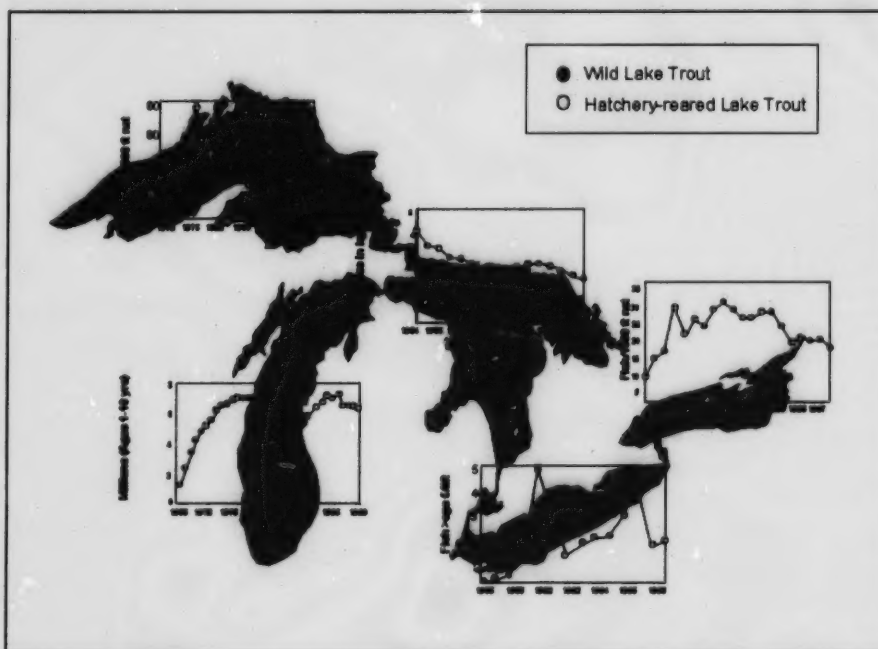
Predation on newly hatched lake trout larvae by native and non-native predators is a problem. Excessive sea lamprey predation will result in few fish reaching sexual maturity. Hatchery-reared fish appear unable to select suitable substrate for egg deposition and genetic diversity is lacking in the strains of hatchery-reared fish stocked into the Lakes. Early mortality syndrome (EMS) of fish

larvae is thought to be due to thiamine deficiencies in the parental diet of alewives.

Acknowledgments

Author: Charles Bronte, U.S. Fish and Wildlife Service, Green Bay, WI.

Contributions by James Bence, Michigan State University, East Lansing, MI, Donald Einhouse, New York Department of Environmental Conservation, Dunkirk, NY, and Robert O'Gorman, U.S. Geological Survey, Oswego, NY.



Lake trout abundance in the Great Lakes.

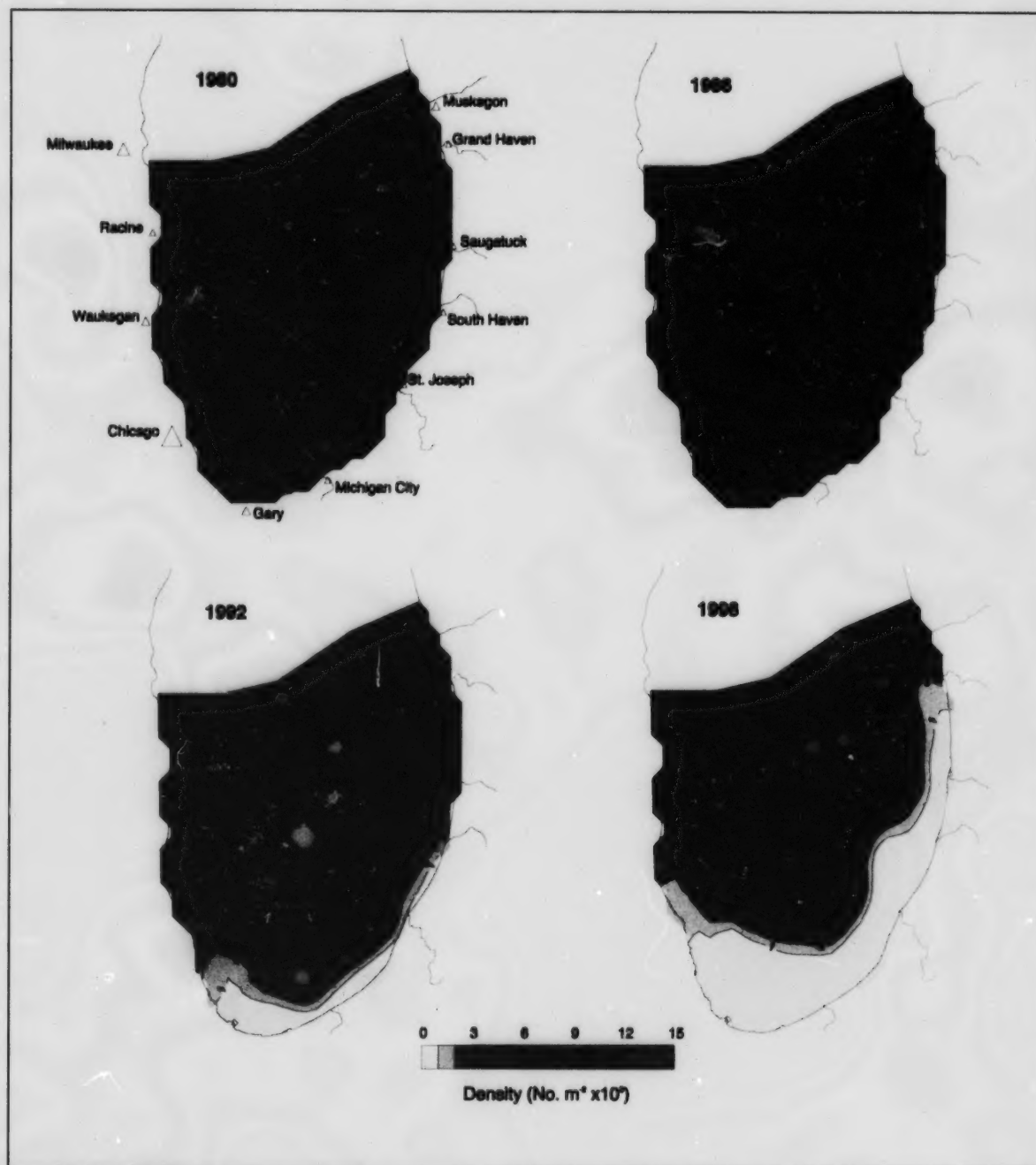
Source: R.L. Eshenroder, Great Lakes Fishery Commission, J.W. Peck, and C.H. Oliver

Scud (*Diporeia hoyi*)

Assessment: Mixed, deteriorating

Purpose

This indicator provides a measure of the biological integrity of the offshore regions of the Great Lakes. It consists of assessing the abundance of the benthic macroinvertebrate *Diporeia*, which are the most abundant benthic organisms in cold, offshore regions of each of the lakes, and which are a key component in the food web of offshore regions.



Density (numbers/m² x 10³) of *Diporeia* in the southern basin of Lake Michigan between 1980 and 1998. Note recent declines in the southeastern portion of the basin.

Source: Great Lakes Environmental Research Laboratory, National Oceanic and Atmospheric Administration

State of the Ecosystem

Populations of *Diporeia* have been observed to decline shortly after zebra mussels become established. *Diporeia* are currently declining in portions of Lake Michigan, Lake Ontario, and eastern Lake Erie (see the figure with the *Hexagenia* indicator report - page 29). Areas where *Diporeia* are known to be rare or absent include the southeastern portion of Lake Michigan from Chicago to Grand Haven at water depths < 70 metres, all of Lake Ontario at depths < 70 metres except for some areas along the northern shoreline, and all of the eastern basin of Lake Erie. In other areas of Lakes Michigan and Ontario, *Diporeia* are still present, but abundances have decreased by one-half or more. Populations appear to be stable in Lake Superior. Recent evidence suggests that the reason for the decline of *Diporeia* may be related to the infestation of zebra mussels.

Future Pressures

Expansion of zebra and quagga mussel populations at water depths of 30-50 metres will pose a threat to *Diporeia*.

Acknowledgments

Author: Thomas Nalepa, National Oceanic and Atmospheric Administration, GLERL, Ann Arbor, MI.

Deformities, Eroded Fins, Lesions and Tumours (DELT) in Nearshore Fish

Assessment: Poor

Purpose

This indicator assesses the prevalence of external anomalies in nearshore fish. It will be used to infer areas where fish are exposed to contaminated sediments within the Great Lakes.

Editor's Note:

The DELT Index (deformities, eroded fins, lesions, and tumours) was developed as a measure for the Index of Biological Integrity (IBI), and it has been included as one of the SOLEC indicators. Although the DELT index

looks at the entire fish community, its inclusion of all species and age groups lessens its discriminatory power in distinguishing amongst levels of contaminant exposure of fish from various tributaries.

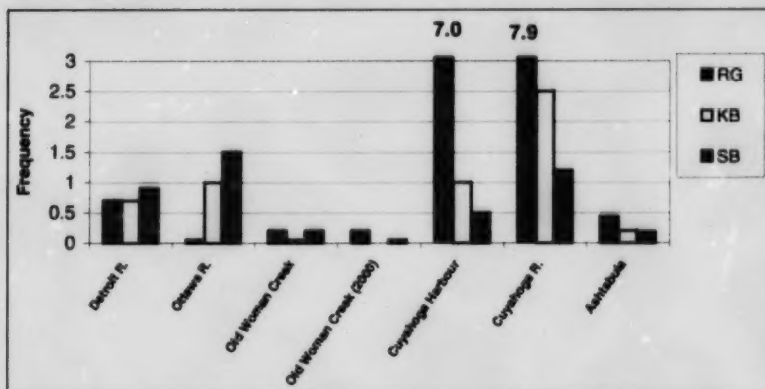
As an alternative indicator, the ELF Index (external lesion frequency) is being developed as an estimate of contaminant exposure of mature fish in a single species. Brown bullhead have been used to develop the index, since they are the most frequently used benthic indicator species in the southern Great Lakes. Information is included here to assist an evaluation of ELF as a SOLEC indicator.

State of the Ecosystem

Field and laboratory studies have correlated chemical carcinogens found in sediments at some Areas of Concern in Lakes Erie, Michigan, and Huron with an elevated incidence of liver and external tumours. Other external anomalies may also be related to exposure to toxic chemicals, but their use must be carefully evaluated.

The most common external anomalies found in bullhead over the last twenty years are raised growths (RG) on the body or lips (often called tumours), focal discoloration (called melanistic spots), and stubbed or shortened/missing barbels (SB). Knobbed barbels (KB) have not been as consistently reported in the historical database, but also appear to be a useful parameter.

Preliminary findings from bullhead populations in several Lake Erie contaminated tributaries and a



External lesion frequency for brown bullheads in Lake Erie, 1999-2000. RG-raised growth, KB-knobbed barbels, SB-stubbed barbels.

Source: Lake Erie Ecological Investigation, unpublished. P. Baumann, U.S. Geological Survey, and D. Peterson, Ohio State University

reference site indicate that single anomalies occurring at > 0.4 per fish or multiple anomalies occurring at greater than 0.8 per fish would indicate possible impairment.

Future Pressures

Continued exposure of the fish populations to contaminated sediments could cause deformities to persist.

Acknowledgments

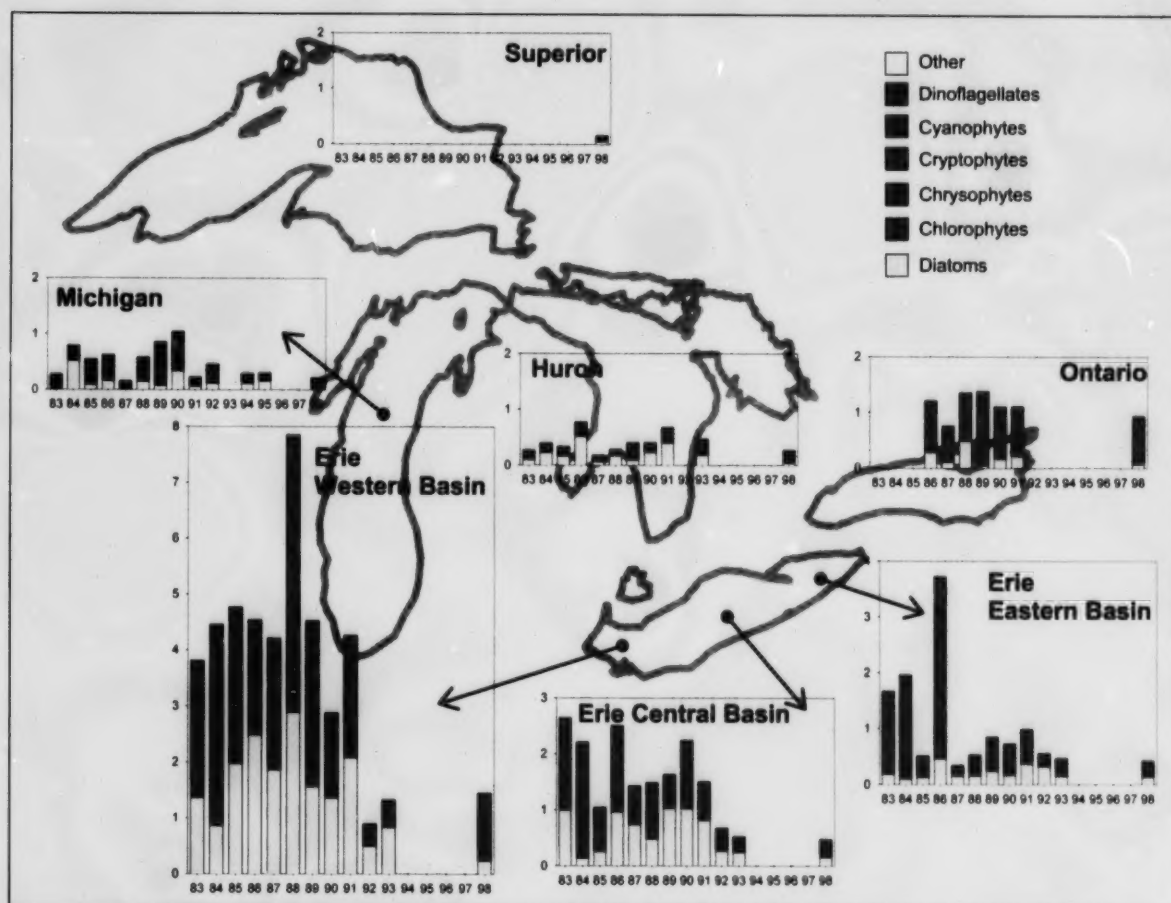
Authors: Stephen B. Smith, U.S. Geological Survey, Biological Resources Division, Reston, VA, and Paul C. Baumann, U.S. Geological Survey, Biological Resources Division, Columbus, OH.

Phytoplankton Populations

Assessment: Unable to assess status until targets are determined

Purpose

This indicator involves the direct measurement of phytoplankton species composition, biomass, and primary productivity in the Great Lakes, and indirectly assesses the impact of nutrient/contaminant enrichment and invasive non-native predators on the microbial food-web of the Great Lakes.



Phytoplankton biovolume (gm/m³) and community comparison in the Great Lakes 1983-1998 (summer, open lake, epilimnion or upper waters). Blank indicates no data.

Source: U.S. Environmental Protection Agency, Great Lakes National Program Office



State of the Ecosystem

Substantial reductions in summer phytoplankton populations occurred in the late 1980s in the eastern basin of Lake Erie and in the early 1990s for the central and western basins. The data were highly variable year-to-year, so possible changes in community composition were not determined. In general, phytoplankton biomass in Lake Michigan was lower in the 1990s than in the 1980s. The timing of these declines in phytoplankton biomass suggest the possible impact of zebra mussels. No trends are apparent in phytoplankton biomass in Lakes Huron or Ontario.

Future Pressures

Pressures on phytoplankton include changes in nutrient loadings; continued introductions and/or expansions of non-native species.

Acknowledgments

Authors: Richard P. Barbiero, DynCorp I&ET, Alexandria, VA, and Marc L. Tuchman, U.S. Environmental Protection Agency, Great Lakes National Program Office, Chicago, IL.

Phosphorus Concentrations and Loadings

Assessment: Mixed

Purpose

This indicator assesses total phosphorus levels in the Great Lakes, and it is used to support the evaluation of trophic status and food web dynamics in the Great Lakes. Phosphorus is an essential element for all organisms and is often the limiting factor for aquatic plant growth in the Great Lakes.

State of the Ecosystem

Strong efforts begun in the 1970s to reduce phosphorus loadings have been successful in maintaining or reducing nutrient concentrations in the Lakes, although high concentrations still occur locally in some embayments and harbours.

Average concentrations in the open waters of Lakes Superior, Michigan, Huron, and Ontario are at or below guideline levels. Concentrations in all three basins of Lake Erie exceed phosphorus guidelines and recent data suggest an increasing trend, however, this may be an effect of large populations

of non-native zebra and quagga mussels. Further research is necessary. In Lakes Ontario and Huron, almost all offshore waters meet the desired guideline although some nearshore areas and embayments showed elevated levels which could promote nuisance algae growths such as the attached green algae, *Cladophora*.

Future Pressures

Current control measures may no longer be sufficient because increasing numbers of people living along the Lakes will exert increasing demands on existing sewage treatment facilities, and additional loadings can be expected.

Acknowledgments

Authors: Scott Painter, Environment Canada, Environmental Conservation Branch, Burlington, ON, and Glenn Warren, U.S. Environmental Protection Agency, Great Lakes National Programs Office, Chicago, IL.

Contaminants in Colonial Nesting Waterbirds

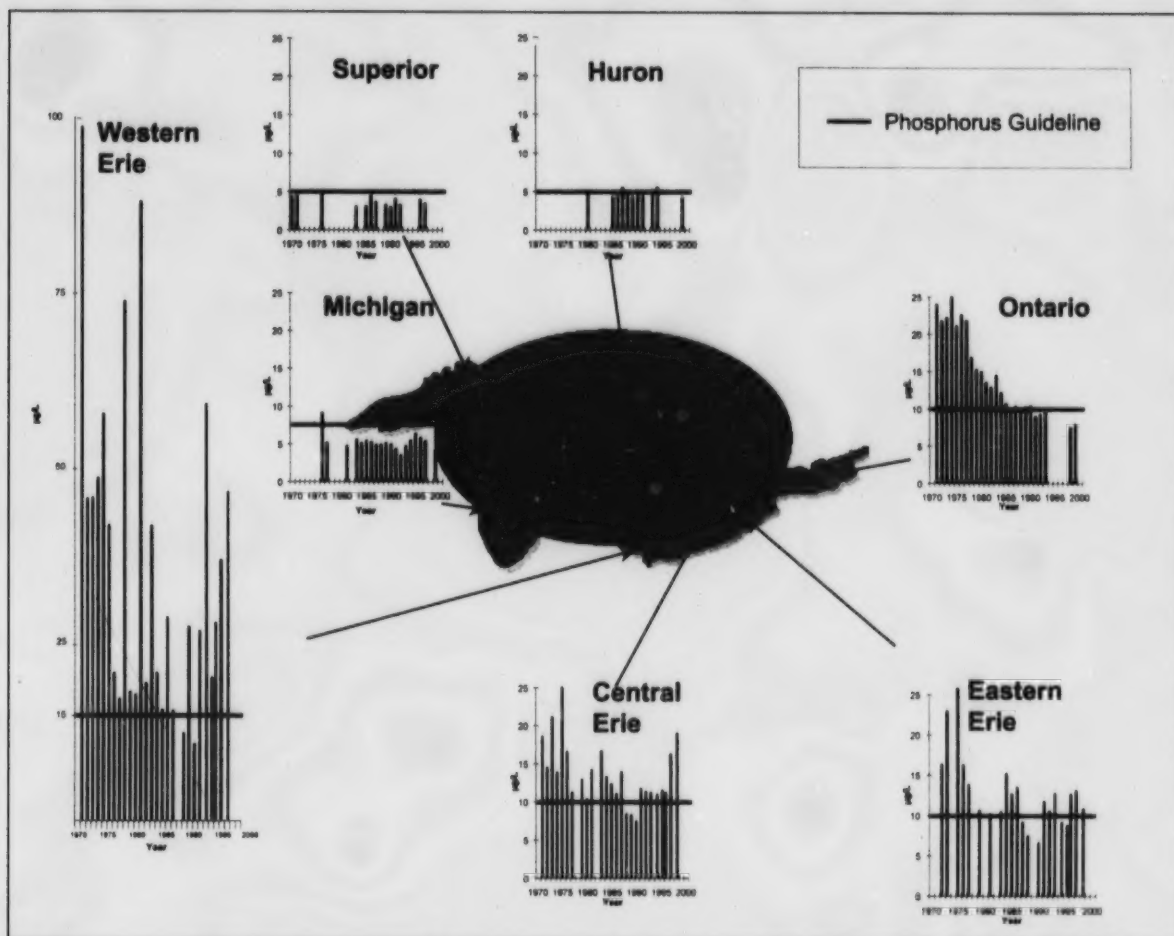
Assessment: Good

Purpose

This indicator assesses current chemical concentration levels and trends as well as ecological and physiological endpoints in representative colonial waterbirds (gulls, terns, cormorants and/or herons). These features will be used to infer the impact of contaminants on the health of the waterbird populations.

State of the Ecosystem

Most contaminants in herring gull eggs have declined by a minimum of 50% and many have declined more than 90% since monitoring began in 1974. As well, the rate of decline in more than 70% of cases is as fast or faster than in the past. Gull eggs from Lake Ontario and the St. Lawrence River continue to have the greatest levels of mirex and dioxin (2,3,7,8 TCDD), those from the upper lakes have the greatest levels of dieldrin and heptachlor epoxide, those from Lake Michigan have the greatest levels of DDE and those from Lake Michigan and the Detroit River-Western Lake Erie area have the greatest levels of PCBs.



Total phosphorus trends in the Great Lakes 1971-2000 (spring, open lake, surface). Blank indicates no sampling.

Source: Environmental Conservation Branch, Environment Canada and U.S. Environmental Protection Agency, Great Lakes National Program Office

Populations of most species have increased over those of 25-30 years ago. Interestingly, Double-crested Cormorants, whose population levels have increased more than 400-fold, still exhibit some eggshell thinning.

Future Pressures

All contaminants entering the Great Lakes including those from re-suspension of contaminated sediments, atmospheric inputs, and underground leaks from landfill sites, will continue to put pressure on colonial nesting waterbirds.

Acknowledgments

Author: D.V. Chip Weseloh, Canadian Wildlife Service, Environment Canada, Downsview, ON.

Thanks to other past and present staff at CWS-Ontario Region (Burlington and Downsview), as well as staff at the CWS National Wildlife Research Centre (Hull, Que.) and wildlife biologists Ray Faber, Ralph Morris, Jim Quinn, John Ryder, Brian Ratcliff and Keith Grasman for egg collections, preparation, analysis and data management over the 27 years of this project.

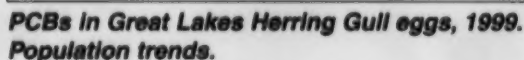


Concentration (ug/g, wet wt.)

Year

Year	Concentration (ug/g, wet wt.)
1974	24
1976	23
1978	14
1980	12
1982	10
1984	12
1986	6
1988	6
1990	4
1992	6
1994	6
1996	2
1998	4
1999	2

Source: C. Pekarik and D.V. Weseloh, Canadian Wildlife Service, unpublished.



40

high. The western basin of Lake Erie and Lake Ontario were both low, while the central basin of Lake Erie had an intermediate value. In the western and central basins of Lake Erie, a significant increase in the ratio of calanoids to cladocerans and cyclopoids was observed between 1970 and 1983-1987, and this increase was sustained throughout the 1990s.

Future Pressures

Zooplankton populations will continue to be affected by invasive non-native species, e.g., the spiny water flea and the fishhook water flea, and continued proliferation of zebra and quagga mussel populations.

Acknowledgments

Authors: Richard P. Barbiero, DynCorp I&ET, Alexandria, VA, Marc L. Tuchman, U.S. Environmental Protection Agency, Great Lakes National Program Office, Chicago IL, and Ora Johannsson, Fisheries and Oceans Canada, Burlington, ON.

Atmospheric Deposition of Toxic Chemicals

Assessment: Mixed, improving

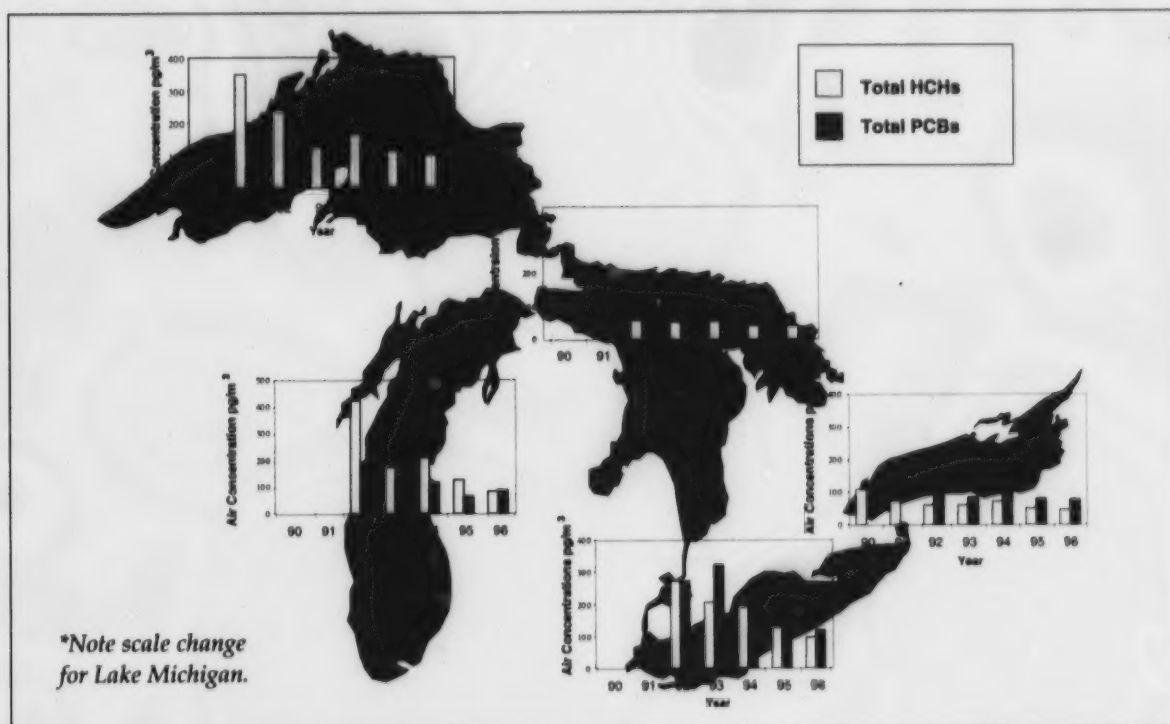
Purpose

This indicator estimates the annual average loadings of priority toxic chemicals from the atmosphere to the Great Lakes, and it is used to determine temporal trends in contaminant concentrations.

State of the Ecosystem

The Integrated Atmospheric Deposition Network (IADN) consists of five master sampling sites, one near each of the Great Lakes, and several satellite stations. The data set is large, and only selected data are presented here.

For gas-phase total PCBs (polychlorinated biphenyls), elevated concentrations were consistently observed at the Lake Erie site compared to the other Lakes. For all sites, the trend over time is generally



Atmospheric concentration of total PCB and total HCH.

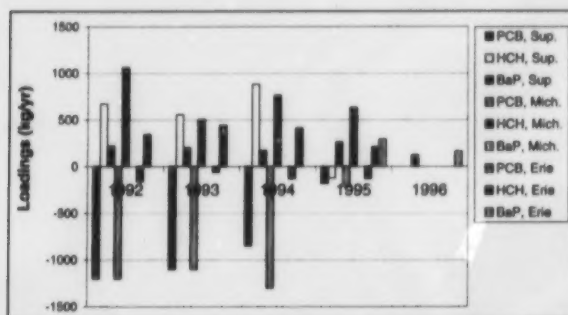
Source: Integrated Atmospheric Deposition Network Steering Committee (2000)



downward. Total PCB concentrations at a satellite site in downtown Chicago were about 10 times higher than at the more remote sites.

Gas-phase α - and γ -HCH (hexachloro-cyclohexane) concentrations declined at all sites until 1996. γ -HCH (lindane) is a pesticide used as a seed treatment in the United States and Canada, and atmospheric concentrations may not decrease further.

The loadings from the atmosphere to the Great Lakes for total PCB, HCH, and BaP (Benzo-[a]-pyrene) are displayed in the accompanying figure. A negative bar indicates that the lake is vaporizing the compound to the atmosphere. A missing bar indicates that the loading could not be calculated, not that the loading was zero. These data show that the loadings are generally getting smaller and the lake water and the air above it are getting closer to being in equilibrium.



Loadings of Total PCBs, Total HCHs, and BaP to the Great Lakes.

Source: Integrated Atmospheric Deposition Network Steering Committee (2000)

Future Pressures

Atmospheric loadings of toxic compounds are likely to continue well into the future.

Acknowledgments

Ron Hites and Ilora Basu at Indiana University prepared this report on behalf of the IADN Steering Committee.

Toxic Chemical Concentrations in Offshore Waters

Assessment: Mixed

Purpose

This indicator reports the concentration of toxic chemicals in offshore waters, and it infers the potential for impacts on the health of the Great Lakes aquatic ecosystem.

State of the Ecosystem

Many toxic chemicals are present in the Great Lakes. Examples of only a few illustrate spatial and temporal trends from a single source of information.

Organochlorine pesticides such as lindane and dieldrin are observed at relatively similar concentrations in all lakes and connecting channels. Concentrations decreased by approximately 50% between 1986 and 1996, but dieldrin still far exceeds the most sensitive water quality criterion for the protection of human consumers of fish.

Hexachlorobenzene (HCB), octachlorostyrene, and mirex are chemicals whose presence is due to historical localized sources. Concentrations of all three in the Niagara River have decreased by more than 50% between 1986 and 1996. However, both HCB and mirex continue to exceed the most stringent criteria for the protection of human consumers of fish.

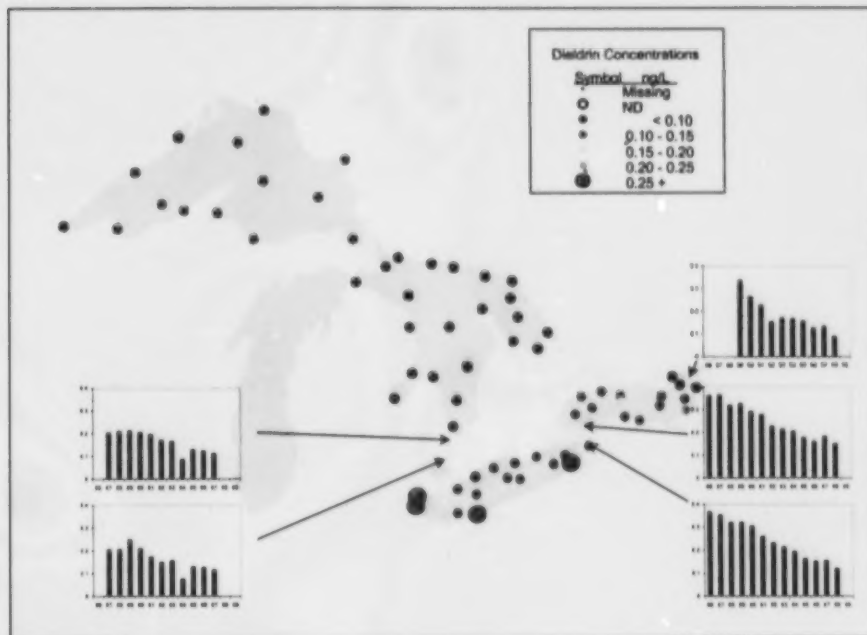
Concentrations of some (not all) polycyclic aromatic hydrocarbons (PAHs) appear to be increasing, suggesting localized sources. For example, comparisons of upstream/downstream concentrations of fluoranthene over time suggest increasing inputs from localized sources in the Niagara River.

Future Pressures

Active sources for some chemicals still exist; classes of chemicals such as endocrine disrupting chemicals, in-use pesticides, and pharmaceuticals are emerging issues.

Acknowledgments

Author: Scott Painter, Environment Canada, Environmental Conservation Branch, Burlington, ON.

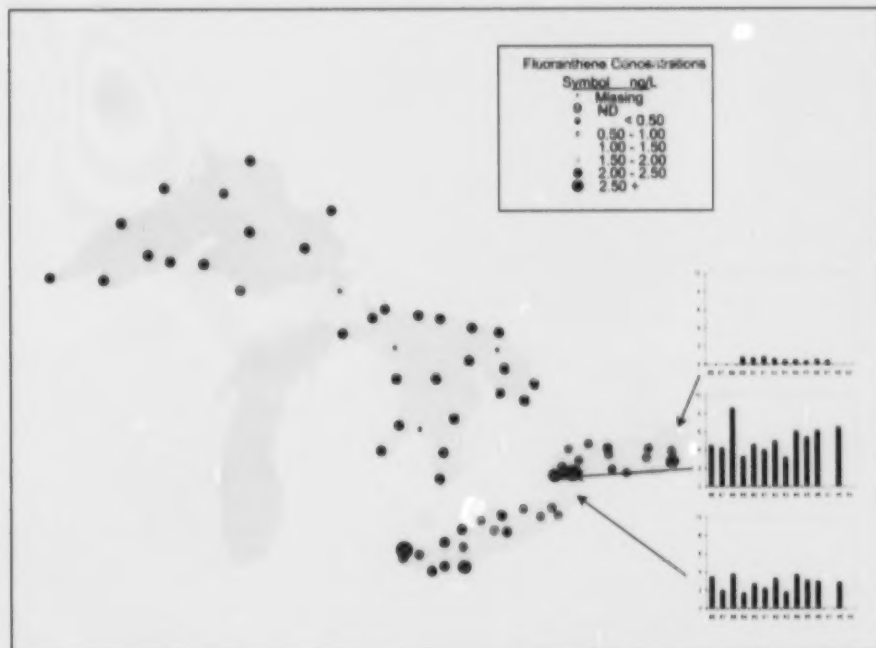


Spatial dieldrin patterns in the Great Lakes (spring 1997 or 1998, surface) and annual most likely estimated averages for the interconnecting channels from 1986 to 1998. Units = ng/L.

Source: Environmental Conservation Branch, Environment Canada

Spatial fluoranthene patterns in the Great Lakes (spring 1997 or 1998, surface) and annual most likely estimated averages for the interconnecting channels from 1986 to 1998. Units = ng/L.

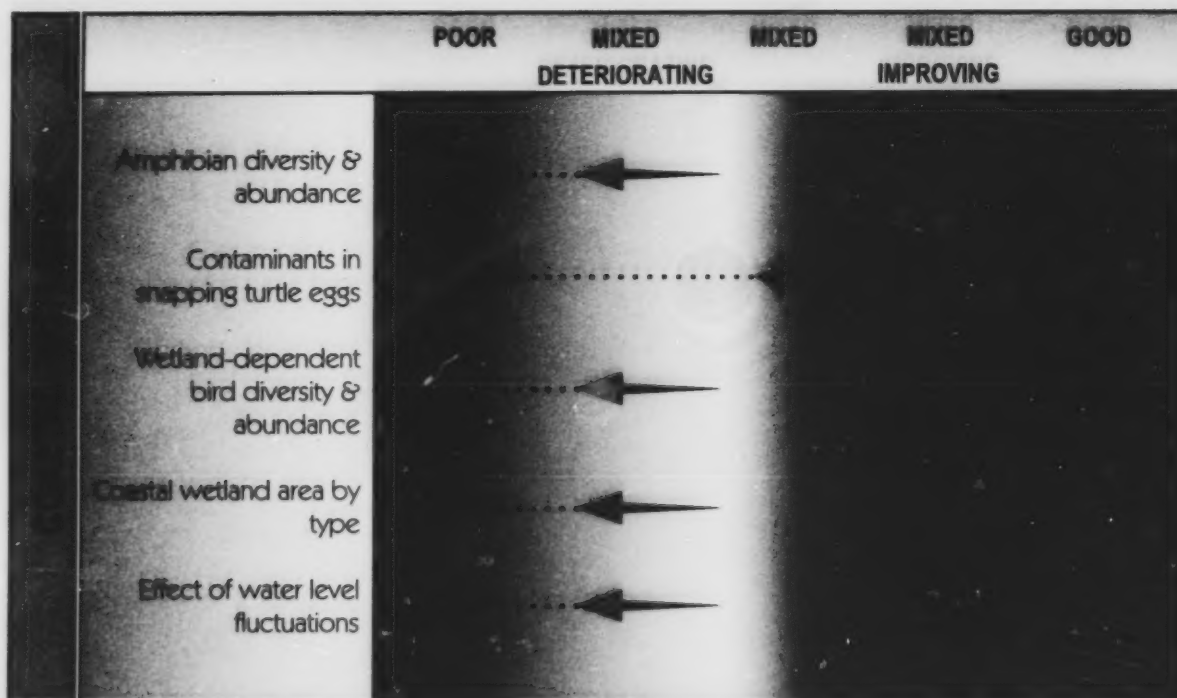
Source: Environmental Conservation Branch, Environment Canada





3.2 Coastal Wetlands

Coastal Wetland Indicators - Assessment at a Glance



Amphibian Diversity and Abundance

Assessment: Mixed, deteriorating

Purpose

Assessments of the species composition and relative abundance of calling frogs and toads are used to help infer the condition of Great Lakes basin marshes (i.e. wetlands dominated by non-woody emergent plants).

State of the Ecosystem

With only five years of data collected across the Great Lakes basin, the Marsh Monitoring Program (MMP) is quite new as a monitoring program. From 1995 through 1999, 11 frog and two toad species were recorded by MMP participants surveying 354

routes across the Great Lakes basin. Spring Peeper was the most frequently detected species. Green Frog was detected in more than half of station years. Gray Treefrog, American Toad and Northern Leopard Frog were also common.

Although some trends were suggested for species such as American Toad and Bullfrog, only the declining trend for Chorus Frog could be resolved with statistical confidence. Anecdotal and research evidence suggests that wide variations in the occurrence of many amphibian species at a given site is a natural and ongoing phenomenon.

Future Pressures

Threats to amphibians include habitat loss and deterioration, water level stabilization,

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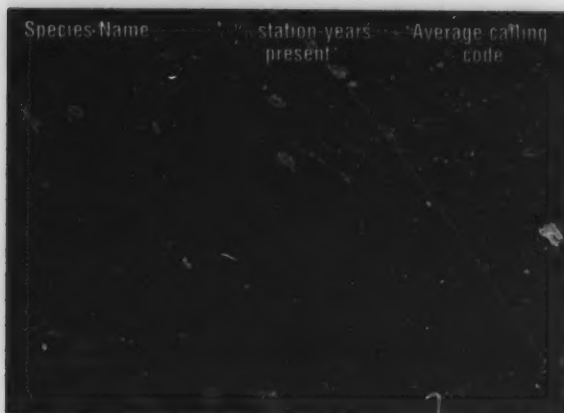
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* MMP Survey stations monitored for multiple years considered as individual samples.

Frequency of occurrence and average Call Level Code for amphibian species detected inside Great Lakes basin MMP stations, 1995 through 1999. Average calling codes are based upon the three level call code standard for all MMP amphibian surveys; surveyors record Code 1 (little overlap among calls, numbers of individuals can be determined), Code 2 (some overlap, numbers can be estimated) or Code 3 (much overlap, too numerous to be estimated).

Source: Marsh Monitoring Program

sedimentation, contaminant and nutrient inputs, and invasion of non-native plants and animals.

Acknowledgments

Author: Russ Weeber, Bird Studies Canada, Port Rowen, ON.

The Marsh Monitoring Program is delivered by Bird Studies Canada in partnership with Environment Canada's Canadian Wildlife Service and with significant support from the U.S. Environmental Protection Agency's Great Lakes National Program Office and Lake Erie Team. The contributions of all Marsh Monitoring Program staff and volunteers are gratefully acknowledged.

Contaminants in Snapping Turtle Eggs

Assessment: Mixed

Purpose

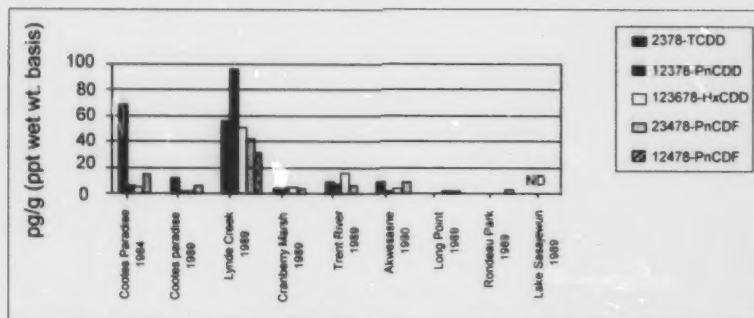
This indicator measures the concentrations of persistent contaminants in the eggs of common snapping turtles living in wetlands of the Great Lakes basin in order to provide an indirect measure of foodweb contamination and its effects on wetland wildlife.

State of the Ecosystem

Snapping turtle eggs collected at two Lake Ontario sites (Cootes Paradise and Lynde Creek) had the highest polychlorinated dioxins (PCDD) concentrations (notably 2,3,7,8-TCDD) and number of detectable furans (PCDF). Eggs from Cranberry Marsh (Lake Ontario) and two Lake Erie sites (Long Point and Rondeau Provincial Park) had similar levels of PCBs and organochlorines. Eggs from Akwesasne (St. Lawrence River) contained the highest level of PCBs relative to all other sites.

Levels of PCBs and DDE (not shown) increased significantly from 1984 to 1990/91 in eggs from Cootes Paradise and Lynde Creek, but levels of PCDDs (including 2,3,7,8-TCDD) and PCDFs decreased significantly at Cootes Paradise during this time.

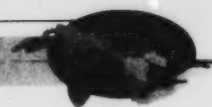
Eggs with the highest contaminant levels also showed the poorest developmental success. Rates of abnormal development of snapping turtle eggs from (1986-1991) were highest at all four Lake Ontario sites compared to all other sites studied.



Dioxin and furan concentrations (1984; 1989/90) in snapping turtle eggs at Canadian Great Lakes study sites.

Source: C. Bishop, Canadian Wildlife Service





Species Name	% station-years present*	Average calling code
Spring Peeper	69	2.5
Green Frog	56.6	1.3
Gray Treefrog	37.9	1.9
American Toad	36.9	1.5
N. Leopard Frog	32.6	1.3
Bullfrog	26.6	1.3
Chorus Frog	25.3	1.7
Wood Frog	18.7	1.5
Pickereel Frog	2.4	1.1
Fowler's Frog	1.4	1.2
Mink Frog	1.3	1.2
Blanchard's Cricket Frog	0.9	1.2
Cope's Gray Treefrog	0.9	1.3

* MMP Survey stations monitored for multiple years considered as individual samples

Frequency of occurrence and average Call Level Code for amphibian species detected inside Great Lakes basin MMP stations, 1995 through 1999. Average calling codes are based upon the three level call code standard for all MMP amphibian surveys: surveyors record Code 1 (little overlap among calls, numbers of individuals can be determined), Code 2 (some overlap, numbers can be estimated) or Code 3 (much overlap, too numerous to be estimated).

Source: Marsh Monitoring Program

sedimentation, contaminant and nutrient inputs, and invasion of non-native plants and animals.

Acknowledgments

Author: Russ Webster, Bird Studies Canada, Fort Rouer, ON

The Marsh Monitoring Program is delivered by Bird Studies Canada in partnership with Environment Canada's Canadian Wildlife Service, and with significant support from the U.S. Environmental Protection Agency's Great Lakes National Program Office and Lake Erie team. The contributions of all Marsh Monitoring Program staff and volunteers are gratefully acknowledged.

Contaminants in Snapping Turtle Eggs

Assessment: Mixed

Purpose

This indicator measures the concentrations of persistent contaminants in the eggs of common snapping turtles living in wetlands of the Great Lakes basin in order to provide an indirect measure of foodweb contamination and its effects on wetland wildlife.

State of the Ecosystem

Snapping turtle eggs collected at two Lake Ontario sites (Cootes Paradise and Lynde Creek) had the highest polychlorinated dioxins (PCDD) concentrations (notably 2,3,7,8-TCDD) and number of detectable furans (PCDF). Eggs from Cranberry Marsh (Lake Ontario) and two Lake Erie sites (Long Point and Rondeau Provincial Park) had similar levels of PCBs and organochlorines. Eggs from Akwesasne (St. Lawrence River) contained the highest level of PCBs relative to all other sites.

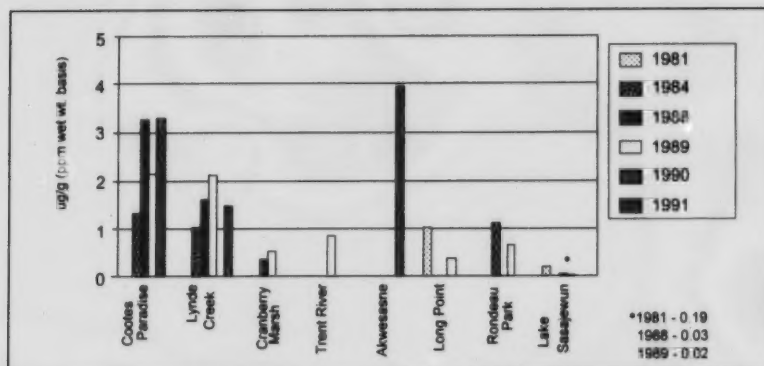
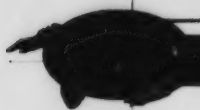
Levels of PCBs and DDE (not shown) increased significantly from 1984 to 1989/90 in eggs from Cootes Paradise and Lynde Creek, but levels of PCDDs (including 2,3,7,8-TCDD) and PCDFs decreased significantly at Cootes Paradise during this time.

Eggs with the highest contaminant levels also showed the poorest developmental success. Rates of abnormal development of snapping turtle eggs from (1986-1991) were highest at all four Lake Ontario sites compared to all other sites studied.



Dioxin and furan concentrations (1984; 1989/90) in snapping turtle eggs at Canadian Great Lakes study sites.

Source: C. Bishop, Canadian Wildlife Service



Mean sum PCB concentrations (1981-1991) in snapping turtle eggs at Canadian Great Lakes study sites and one inland reference site.

Source: C. Bishop, Canadian Wildlife Service

Future Pressures

Snapping turtles in some Great Lakes locations will continue to be exposed to toxic chemicals through a diet of contaminated fish.

Acknowledgments

Author: Kim Hughes, Canadian Wildlife Service, Environment Canada, Downsview, ON.

Contributions from Christine Bishop, Canadian Wildlife Service, Environment Canada, R.J. Brooks, University of Guelph, Canadian Wildlife Service - National Wildlife Research Centre and Peggy Ng, York University.

Wetland-Dependent Bird Diversity and Abundance

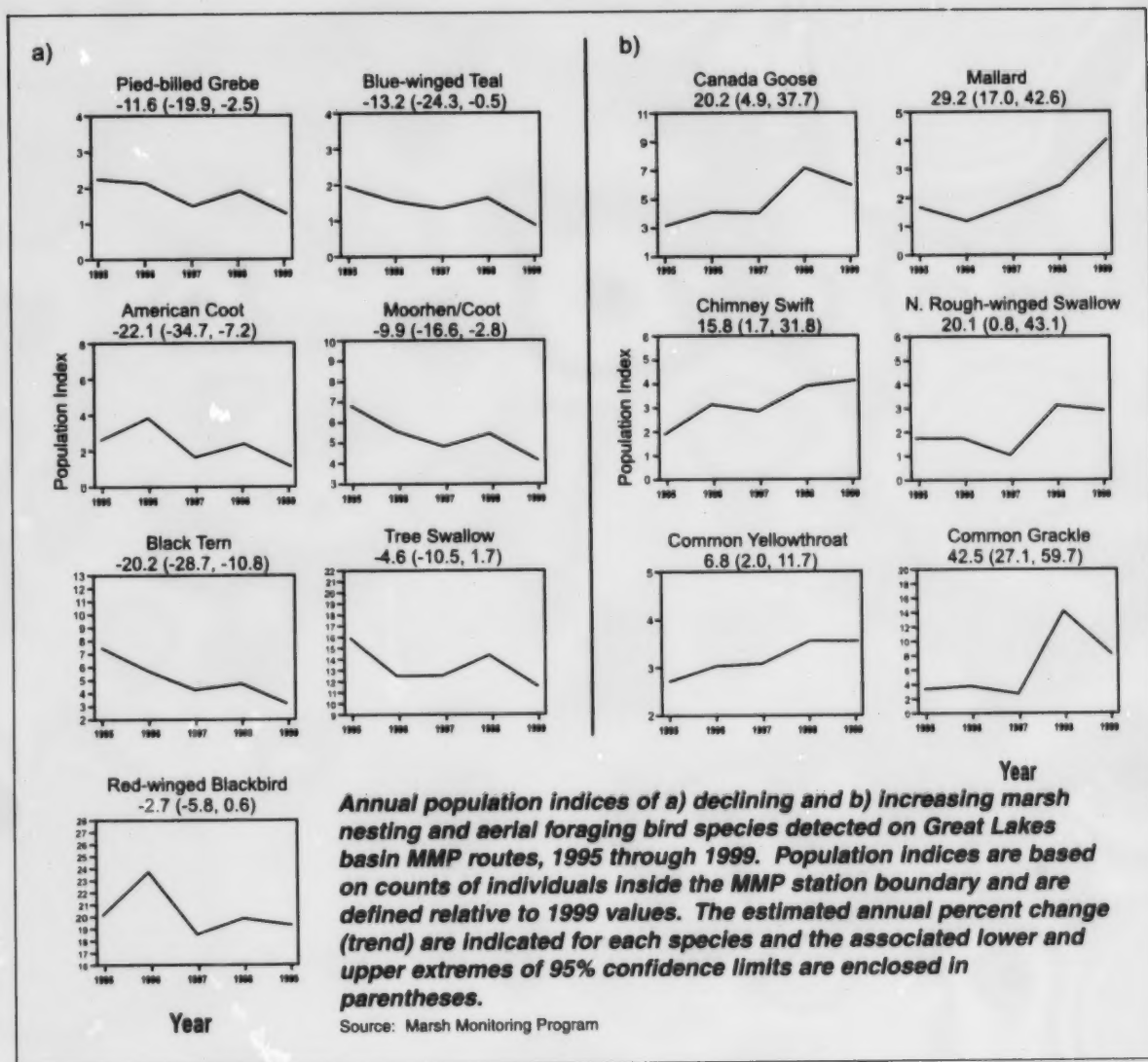
Assessment: Mixed, deteriorating

Purpose

Assessments of the diversity and abundance of wetland-dependent birds in the Great Lakes basin, combined with an analysis of habitat characteristics, are used to evaluate the health and function of wetlands.

State of the Ecosystem

Although results are still preliminary, from 1995 through 1999, 53 species of birds that use marshes (wetlands dominated by non-woody emergent plants) for feeding, nesting or both were recorded by Marsh Monitoring Program (MMP) volunteers at 322 routes throughout the Great Lakes basin. Statistically significant basin-wide increases were observed for Canada Goose, Mallard, Chimney Swift, Northern Rough-winged Swallow, Common Yellowthroat and Common Grackle. Species with significant basin-wide declines were Pied-billed Grebe, Blue-winged Teal, American Coot, undifferentiated Common Moorhen/American Coot, and Black Tern. Each of the declining species depends upon wetlands for breeding, but because they use wetland habitats almost exclusively, the Pied-billed Grebe, American Coot, Common Moorhen, and Black Tern are particularly dependent on the availability of healthy wetlands.



Future Pressures

Continuing loss and degradation of important breeding habitats through wetland loss, water level stabilization, sedimentation, contaminant and nutrient inputs, and the invasion of non-native plants and animals will continue putting pressure on these bird populations.

Acknowledgments

Author: Russ Weeber, Bird Studies Canada, Port Rowen, ON.

The Marsh Monitoring Program is delivered by Bird Studies in partnership with Environment Canada's Canadian Wildlife Service and with significant support from the U.S. Environmental Protection Agency's Great Lakes National Program Office and Lake Erie Team. The contributions of all Marsh Monitoring Program staff and volunteers are gratefully acknowledged.

Coastal Wetland Area by Type

Assessment: Mixed, deteriorating

Purpose

The purpose of this indicator is to examine and better understand periodic changes in area of coastal wetland types, taking into account natural variations in areal extent and changes within wetlands.

State of the Ecosystem

Wetlands continue to be lost and degraded, yet the ability to track and determine the extent and rate of this loss in a standardized way is not yet feasible.

Adding up the area of individual wetlands from the Ontario Coastal Wetland Atlas will provide an initial estimate of the total Canadian Great Lakes coastal wetland area. This process is unlikely to be repeated, however, since it is labour intensive, expensive, and covers a very large geographic area.

Other methods to look at trends in coastal wetland area rely on remotely sensed data. For example, the U.S. Fish and Wildlife Service published the National Wetland Inventory (NWI) in 1982, based on the analysis of aerial photographs with ground-truth. The NWI includes delineated wetland types with updates to be prepared every 10 years. The first one was in 1990. Updates are based on a statistical sampling of wetlands, not on a full set of aerial photos. The NWI, however, does not specifically identify coastal wetlands.

Numerous research efforts are underway to assess the use of remote sensing technologies, and in some cases combine the results of satellite remote sensing, aerial photography and field work to document recent wetland loss. In the future, remote sensing will be used to provide an overview and facilitate a binational map of Great Lakes coastal wetlands as well as to establish a consistent methodology for tracking change and to facilitate faster updates in areas of high land-use change.

Future Pressures

Reductions in wetland area are continuing from filling, dredging and draining for conversion to other uses such as urban, agricultural, marina, and cottage development; shoreline modification; water level regulation; sediment and nutrient loading from

watersheds; adjacent land use; non-native invasive species; and climate variability and change.

Acknowledgments

Authors: Lesley Dunn, Canadian Wildlife Service, Environment Canada, Downsview, ON and Laurie Maynard, Canadian Wildlife Service, Environment Canada, Guelph, ON.

Contributions from Doug Forder, Canadian Wildlife Service, Environment Canada, Duane Heaton, U.S. Environmental Protection Agency, Linda Mortsch, Meteorological Service of Canada, Environment Canada, Nancy Patterson, Canadian Wildlife Service, Environment Canada and Brian Potter, Ontario Ministry of Natural Resources.

Effects of Water Level Fluctuations

Assessment: Mixed, deteriorating

Purpose

The purpose of this indicator is to assess the lake level trends that may significantly affect components of wetland and nearshore terrestrial ecosystems, and to infer the effect of water level regulation on emergent wetland extent.

State of the Ecosystem

Quasi-periodic lake level fluctuations, both in period and amplitude, occur on an average of about 160 years, with sub-fluctuations of approximately 33 years. The levels in Lakes Michigan and Huron show the characteristic high and low water levels. Data for Lake Ontario show these fluctuations, but their amplitude has been reduced since the Lake level began to be regulated by various dams in 1959.

During periods of high water, there is a die-off of species that cannot tolerate long periods of increased depth of inundation. As the water levels recede, seeds buried in the sediments germinate and vegetate the newly exposed zone. During periods of low water, woody plants and emergents become established. This is the 'normal' relationship between wetlands and fluctuating water levels.

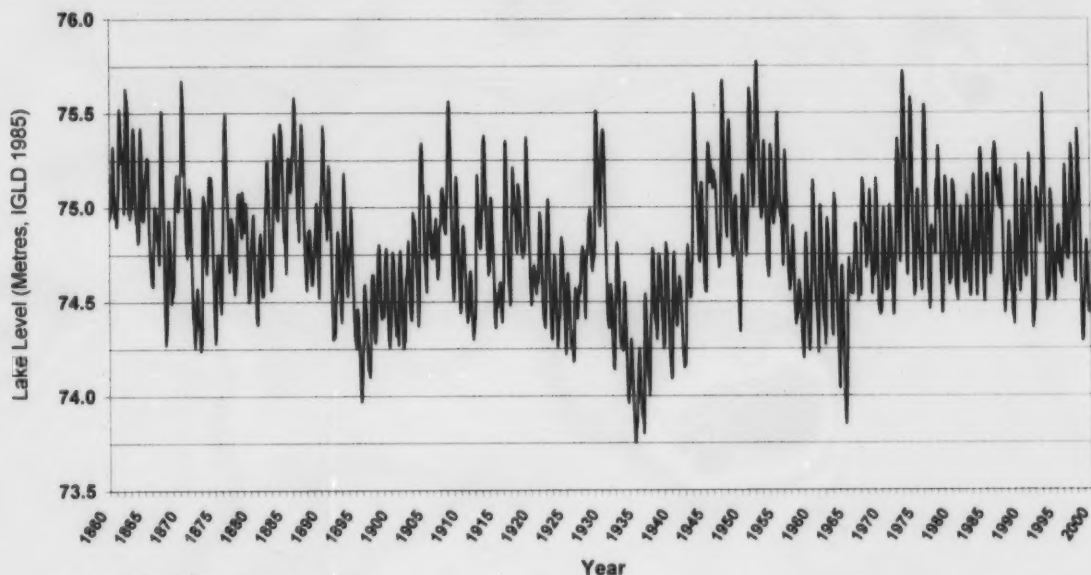
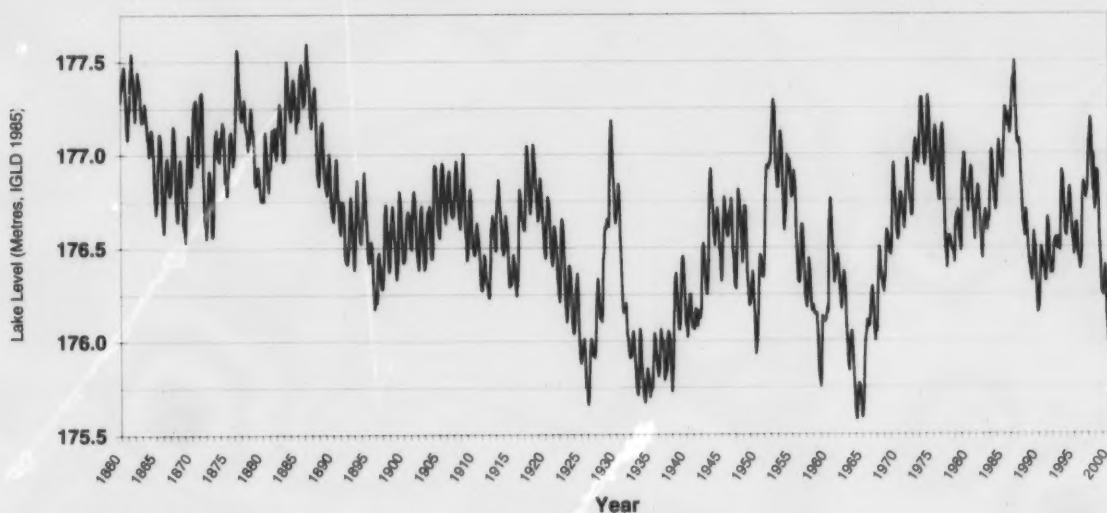
Under more stable water levels, such as in Lake Ontario, coastal wetlands occupy narrower zones along the Lakes and are considerably less diverse because dominant species such as cattails take over.

CORRECTION

The figures are mislabeled.

Upper = Lake Ontario

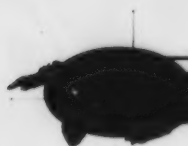
Lower = Lake Michigan-Huron

**Lake Michigan-Huron Actual Levels.****Lake Ontario Actual Levels.**

Actual water levels for Lakes Huron and Michigan (upper) and Lake Ontario (lower).

IGLD-International Great Lakes Datum. Zero for IGLD 1985 is Rimouski, Quebec, at the mouth of the St. Lawrence River. Water level elevations in the Great Lakes/St. Lawrence River system are measured above water level at this site.

Source: National Oceanic and Atmospheric Administration



Future Pressures

Future pressures include additional withdrawals or diversions of water from the Lakes; additional regulation or smoothing of the high and low water levels; and global climate variability and change.

Acknowledgments

Author: Duane Heaton, U.S. Environmental Protection Agency, Chicago, IL.

Contributions from Douglas A. Wilcox, U.S. Geological Survey, Biological Resources Division, Todd A. Thompson, Indiana Geological Survey, and Steve J. Baedke, James Madison University.

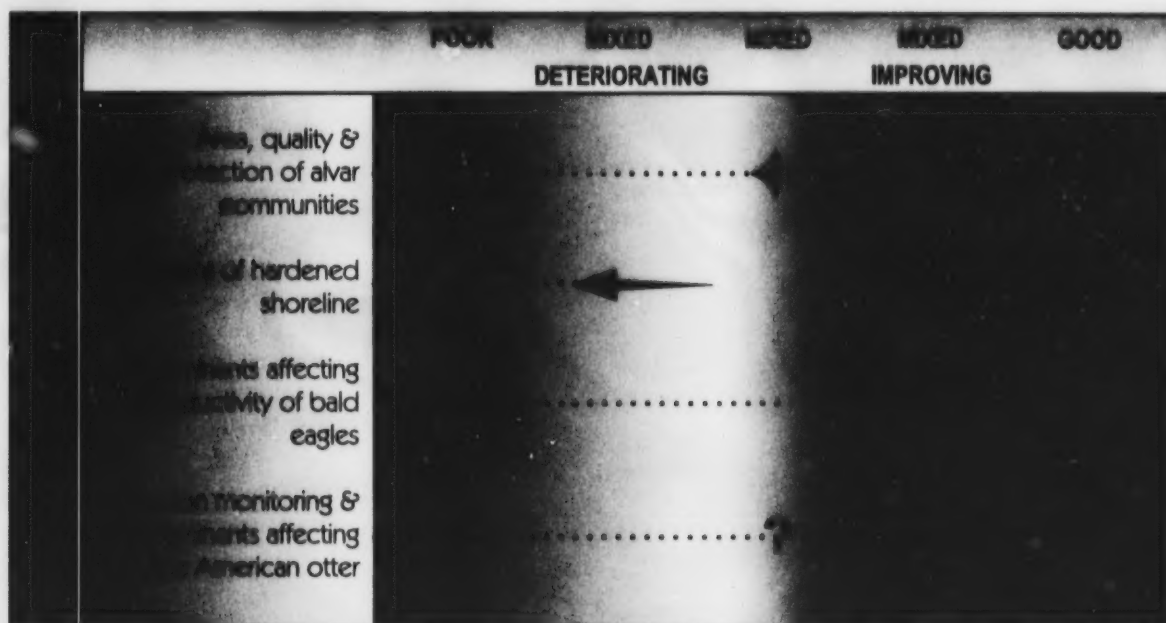


Time series at Fish Point (east shore of Saginaw Bay, Lake Huron) from 1988 to 1993 showing the effects of fluctuating water levels on a coastal wetland.

Photo credits: Douglas A. Wilcox, U.S. Geological Survey

3.3 Nearshore Terrestrial

Nearshore Terrestrial Indicators - Assessment at a Glance



Area, Quality and Protection of Alvar Communities

Assessment: Mixed

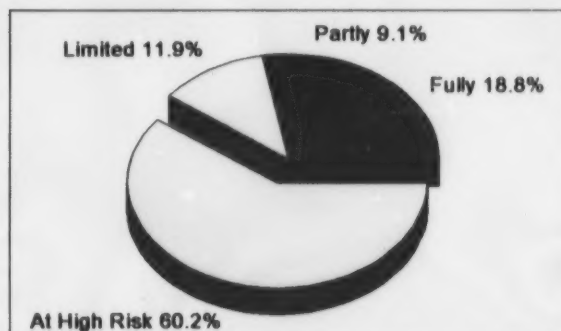
Purpose

This indicator assesses the status of one of the 12 special lakeshore communities identified within the nearshore terrestrial area. Alvar communities are naturally open habitats occurring on flat limestone bedrock.

State of the Ecosystem

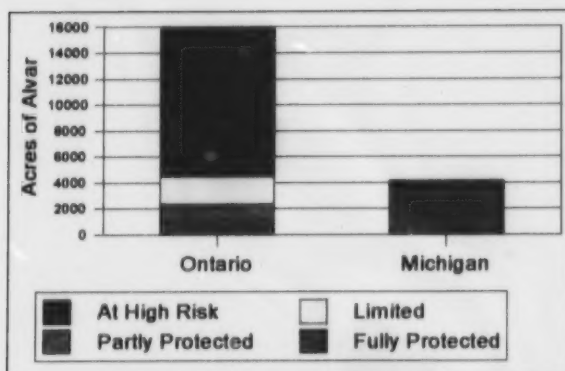
More than 90% of the original extent of alvar habitats has been destroyed or substantially degraded. Emphasis is focused on protecting the remaining 10%. Approximately 64% of the remaining alvar area exists within Ontario, 16% in New York State, 15% in Michigan, and smaller areas in Ohio, Wisconsin and Quebec.

Less than 20% of the nearshore alvar acreage is currently fully protected, while over 60% is at high risk. Michigan has 66% of its nearshore alvar acreage in the Fully Protected category, while Ontario has only 7%. In part, this is a reflection of the much larger total shoreline acreage in Ontario.



Protection status 2000. Nearshore alvar acreage.

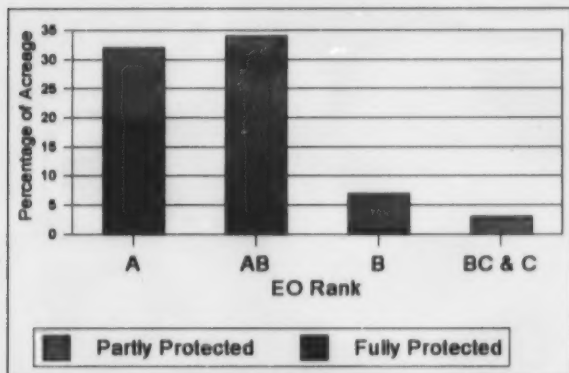
Source: Ron Reid, Bobolink Enterprises



Comparison of acreage protected. Nearshore alvars: Ontario and Michigan.

Source: Ron Reid, Bobolink Enterprises

Each alvar community occurrence has been assigned an "EO (Element Occurrence) rank" to reflect its relative quality and condition. (EO ranks summarize the quality and condition of each individual alvar community at a site, based on standardized criteria for size, site condition, and landscape content.) A and B-ranks are considered viable, while C-ranks are marginal and D ranks are poor. Protection efforts to secure alvars have clearly focused on the best quality sites. Recently, 10 securement projects have resulted in protection of at least 5,289 acres of alvars across the Great Lakes basin.



Protection of high quality alvars.

Source: Ron Reid, Bobolink Enterprises

Future Pressures

Continuing pressures on alvars include habitat fragmentation and loss; trails; off-road vehicles; resource extraction uses such as quarrying or logging; adjacent land uses such as residential subdivisions; grazing or deer browsing; plant collecting for bonsai or other hobbies; and invasion by non-native plants.

Acknowledgments

Authors: Ron Reid, Bobolink Enterprises, Washago, ON, and Heather Potter, The Nature Conservancy, Chicago, IL.

Extent of Hardened Shoreline

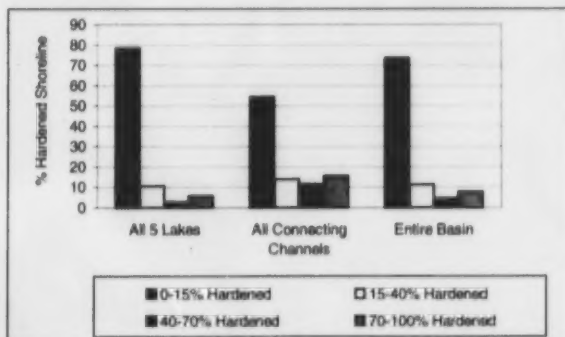
Assessment: Mixed, deteriorating

Purpose

This indicator assesses the extent of hardened shoreline through the construction of sheet piling, rip rap, or other erosion control structures. Shoreline hardening not only directly destroys natural features, but also disrupts biological communities that are dependent upon the transport of shoreline sediment by lake currents. Hardening also destroys inshore habitat for fish, birds and other biota.

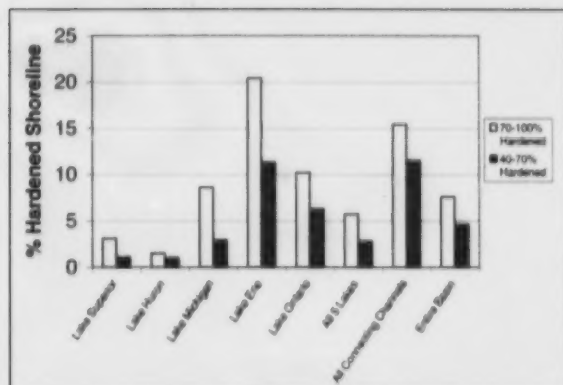
State of the Ecosystem

The St. Clair, Detroit, and Niagara Rivers have a higher percentage of their shorelines hardened than anywhere else in the basin. Of the Lakes



Shoreline hardening in the Great Lakes (compiled from 1979 data for the state of Michigan and 1987-1989 data for rest of the basin).

Source: Environment Canada and National Oceanic and Atmospheric Administration



Shoreline hardening by lake (compiled from 1979 data for the state of Michigan and 1987-1989 data for rest of the basin).

Source: Environment Canada and National Oceanic and Atmospheric Administration

themselves, Lake Erie has the highest percentage of its shoreline hardened, and Lakes Huron and Superior have the lowest.

Along about 22 kilometres of the Canadian side of the St. Clair River, an additional 5.5 kilometres (32%) of the shoreline had been hardened over the 8-year period from 1991 to 1999. This rate of hardening is not representative of the overall basin, however. The St. Clair River is a narrow shipping channel with high volumes of Great Lakes traffic, and many property owners are hardening the shoreline to reduce the impacts of erosion.

Future Pressures

Shoreline hardening can be considered a permanent feature and additional stretches of shoreline will be hardened, especially during periods of high lake levels. This additional hardening will, in turn, starve the downcurrent areas of sediment to replenish the eroded materials and causes further erosion and further incentive for additional hardening.

Acknowledgments

Authors: John Schneider, U.S. Environmental Protection Agency, Great Lakes National Program Office, Chicago, IL, Duane Heaton, U.S. Environmental Protection Agency, Great Lakes National Program Office, Chicago, IL, and Harold Leadlay, Environment Canada, Environmental Emergencies Section, Downsview, ON.

Contaminants Affecting Productivity of Bald Eagles

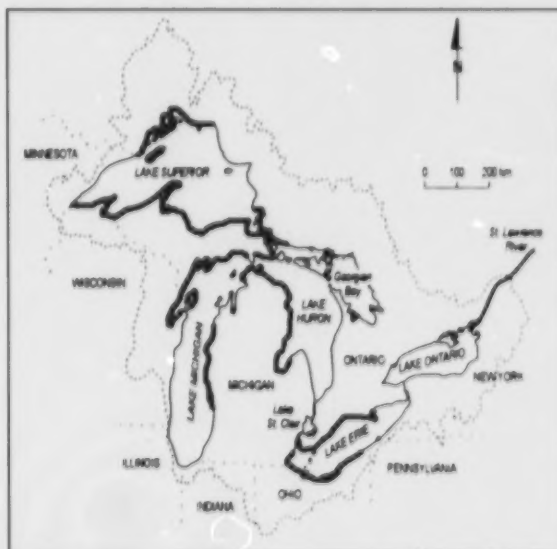
Assessment: Mixed, improving

Purpose

This indicator assesses the number of fledged young, number of developmental deformities, and the concentrations of organic contaminants and heavy metals in bald eagle eggs, blood, and feathers. The data will be used to infer the potential for harm to other wildlife and human health through the consumption of contaminated fish.

State of the Ecosystem

The concentrations of p,p'-DDE, total PCBs, and mercury in blood plasma and feathers of nestling bald eagles in Michigan are either stable or declining from concentrations observed in the late 1980s and early 1990s. The majority (>95%) of eggs tested, however, exhibited contaminant concentrations greater than No Observed Adverse Effects Concentrations (NOAECs) for PCBs and p,p'-DDE, and the number of observed developmental deformities has increased over time.



Approximate nesting locations of bald eagles along the Great Lakes shorelines, 2000.

Source: W. Bowerman, Clemson University, Lake Erie and Lake Superior LaMPs, and for Lake Ontario, Peter Nye, NY Department of Environmental Conservation



The number of nestling eagles fledged from nests along the shorelines of the Great Lakes has steadily increased from six in 1977 to over 200 in 2000, including the first record of a nesting pair along the shoreline of Lake Ontario.

Future Pressures

Pressures on bald eagles include continued exposure, through food chain mechanisms, to environmental pollutants; human related disturbances near nest sites; food availability; loss of habitat due to development; and the loss of protection after delisting from the U.S. Endangered Species list. For those eagles nesting above barrier dams, there is the potential for fish passage of contaminated Great Lakes fishes.

Acknowledgments

Authors: William Bowerman, Clemson University; David Best, U.S. Fish & Wildlife Service, and Michael Gilbertson, International Joint Commission.

Population Monitoring & Contaminants Affecting the American Otter

Assessment: Insufficient data to assess

Purpose

This indicator directly measures the contaminant concentrations found in American otter populations within the Great Lakes basin, and it indirectly measures the health of Great Lakes habitat, progress in Great Lakes ecosystem management, and/or concentrations of contaminants present in the Great Lakes.

State of the Ecosystem

General otter population indices derived from state and provincial data indicate that primary areas of suppression still exist in western Lake Ontario watersheds, southern Lake Huron watersheds, lower Lake Michigan and most Lake Erie watersheds. Data suggest that otter are almost absent in western Lake Ontario. Most coastal shoreline areas have more suppressed populations than interior zones and Great Lakes drainage populations.

Areas of otter population suppression are directly related to human population centres and subsequent habitat loss.

Future Pressures

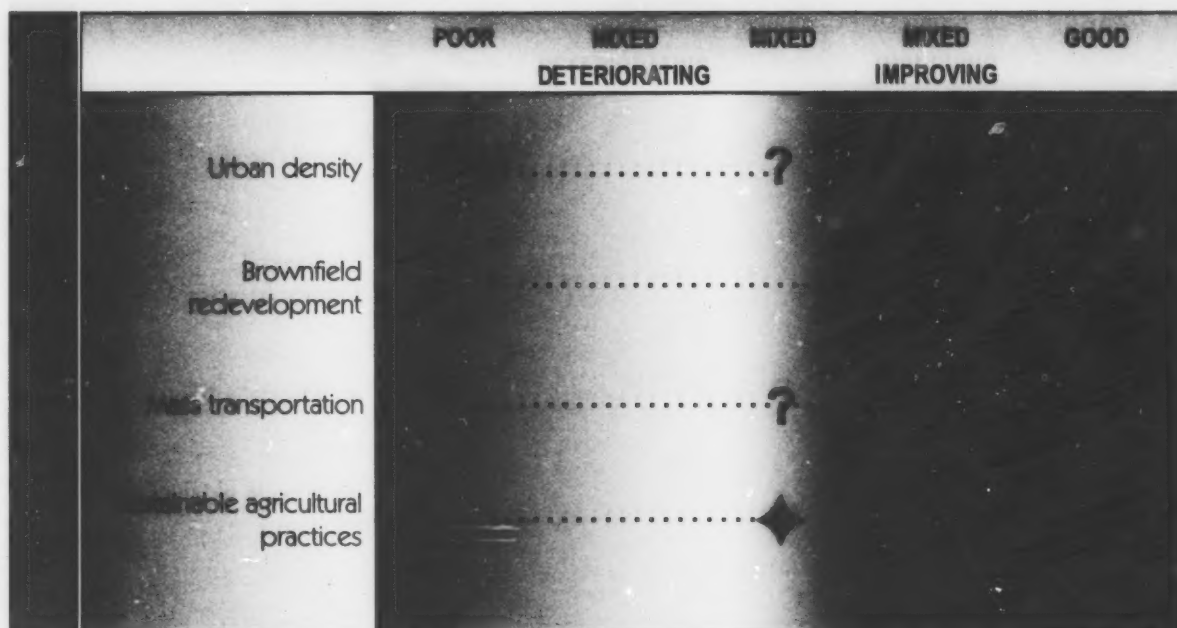
Otter will continue to be under pressure from organic and heavy metal concentrations in the food chain, and anthropogenic alterations of river and lake habitats.

Acknowledgments

Author: Thomas C.J. Doolittle, Bad River Tribe of Lake Superior Chippewa Indians, Odanah, WI.

3.4 Land Use

Land Use Indicators - Assessment at a Glance



Urban Density

Assessment: Unable to assess status until targets are determined

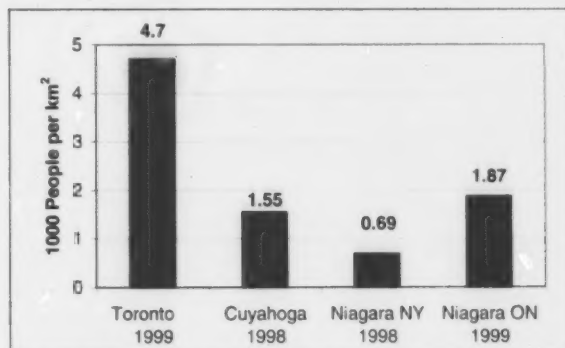
Purpose

This indicator measures human population density and indirectly measures the degree of inefficient land use and urban sprawl for communities in the Great Lakes basin. The number of people that inhabit a community relative to its size is an indicator of the economic efficiency of that community based on the existence of 'economies of scale' associated with high density development.

State of the Ecosystem

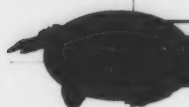
There are marked differences around the Great Lakes basin in communities' urban densities. Initial research compared the larger more established urban cities of Toronto, Ontario and Cuyahoga County,

Ohio (which includes Cleveland) and the two smaller communities of the Regional Municipality of Niagara, Ontario and Niagara County, New York. Factors such as ongoing 'rust belt' U.S. population



Urban densities in four Great Lakes urban communities.

Source: Rivers Consulting and J. Barr Consulting



declines may be partly responsible for the statistical differences in urban densities.

Trends over the last ten years indicate that population densities are increasing in both of the Canadian communities sampled and are stable to declining in the U.S. communities.

Future Pressures

Continued urban sprawl and low density development throughout the basin represent significant pressures.

Acknowledgments

Authors: Ray River, Rivers Consulting, Campbellville, ON, and John Barr, Burlington, ON.

Brownfields Redevelopment

Assessment: Mixed, improving

Purpose

This indicator assesses the acreage of redeveloped brownfields, and it is used to evaluate over time the rate at which society rehabilitates and reuses former developed sites that have been degraded or abandoned.

State of the Ecosystem

Information on acres of brownfields remediated from Illinois, Minnesota, New York, and Pennsylvania indicates that a total of 28,789 acres of

brownfields have been remediated in these jurisdictions alone. Available data from six Great Lakes states indicate that more than 8,662 brownfield sites have participated in brownfields cleanup programs. Though there are inconsistent and inadequate data on acres of brownfields remediated and/or redeveloped, available data indicate that both brownfields cleanup and redevelopment efforts have risen dramatically since the mid 1990s. This is due to the new wave of risk-based cleanup standards and widespread use of state liability relief mechanisms that allow private parties to redevelop, buy or sell property without being held liable for contamination they did not cause. Data also indicate that the majority of cleanups in Great Lakes states and provinces are occurring in older urbanized areas, many of which are located on the Great Lakes and in the basin. Based on this information, the state of brownfields redevelopment is good and improving.

Future Pressures

Continued pressures include: lack of long-term monitoring and enforcement of exposure controls (examples of exposure control include capping a site with clean soil or restricting the use of ground water); cleanup standards based on risks to human health that may not be appropriate for habitat creation/enhancement; the potential for contaminated groundwater to interface with surface waters and cause degradation of surface waters; and policies that encourage new development to occur outside already developed areas over urban brownfields.

Acknowledgments

Author: Victoria Pebbles, Great Lakes Commission, Ann Arbor, MI.



Brownfield site in Detroit, Michigan, 1998.

Photo Credit: Victoria Pebbles, Great Lakes Commission

Mass Transportation

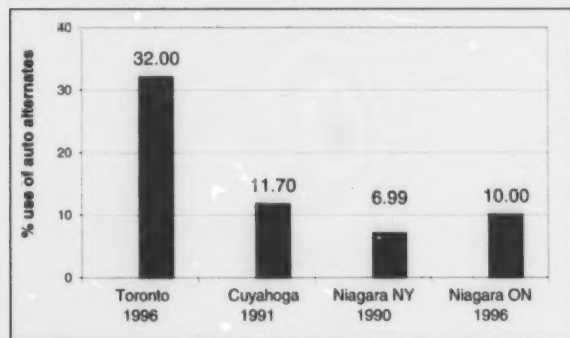
Assessment: Unable to assess status until targets are determined

Purpose

This indicator measures the percentage of daily commuters that use public transportation or other alternatives to the private car. It indirectly measures the stress to the Great Lakes ecosystem caused by the use of the private motor vehicle and its resulting high resource utilization and creation of pollution.

State of the Ecosystem

There are marked differences amongst four sample Great Lakes basin communities in automobile usage for commuting. Initial research showed that there is a direct relationship between public transportation and the degree of urban density. Higher usage of transportation alternatives occurs within the larger more established urban cities of Toronto, Ontario and Cuyahoga County, Ohio (which includes Cleveland) than within the more lightly populated and smaller communities of the Regional Municipality of Niagara, Ontario and Niagara County, New York. This relationship was pronounced in Toronto where higher density also facilitated greater use of bicycling and walking amongst urban commuters.



Percentage of commuters using alternatives to automobiles in selected communities.

Source: Rivers Consulting and J. Barr Consulting

Future Pressures

Significant pressures arguing for more mass transportation are population growth combined with urban sprawl.

Acknowledgments

Authors: Ray Rivers, Rivers Consulting, Campbellville, ON, and John Barr, Burlington, ON.

Sustainable Agricultural Practices

Assessment: Mixed

Purpose

This indicator assesses the number of Environmental and Conservation farm plans and environmentally friendly agricultural practices in place, such as integrated pest management to reduce the potential adverse impacts of pesticides, and conservation tillage and other soil preservation practices to reduce energy consumption, prevent ground and surface water contamination, and achieve sustainable natural resources.

State of the Ecosystem

Agriculture accounts for 35% of the land area of the Great Lakes basin and dominates the southern portion of the basin. In the past, excessive tillage and intensive crop rotations led to soil erosion and the resulting sedimentation of major tributaries. Agriculture is a major user of pesticides with an annual use of 26,000 tons. These practices led to a decline of soil organic matter. Recently there has been increasing cooperation between government and the farm community on Great Lakes water quality management programs. The adoption of more environmentally responsible practices has helped to replenish carbon in the soils back to 60% of turn-of-the-century levels.

Both the Ontario Ministry of Agriculture, Food and Rural Affairs (OMAFRA) and the USDA's Natural Resources Conservation Service (NRCS) provide conservation planning advice, technical assistance and incentives to farm clients and rural landowners. On a voluntary basis clients develop and implement conservation plans to protect, conserve, and enhance natural resources that harmonize productivity, business objectives and the environment.

Future Pressures

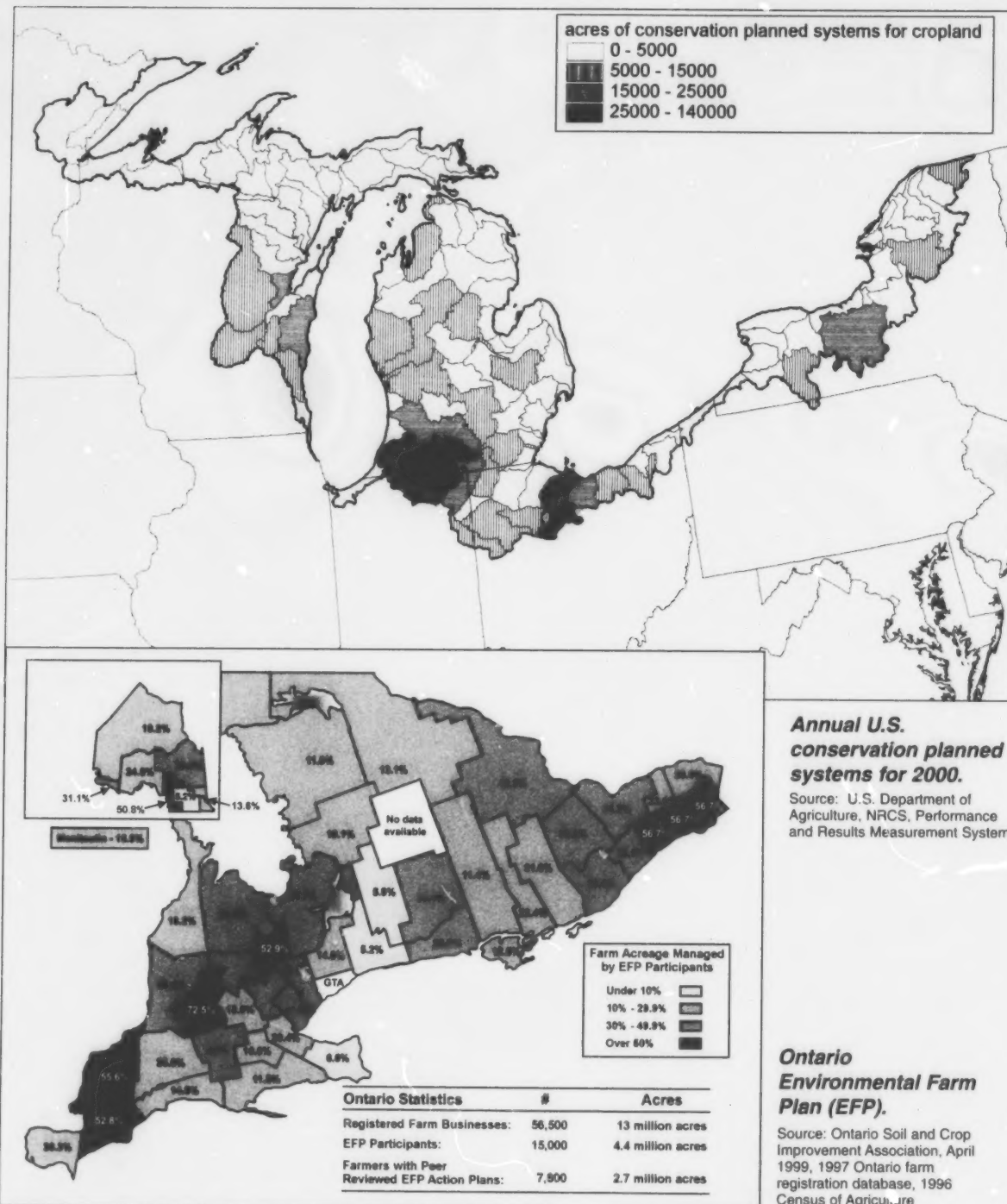
Sustainable agricultural practices will be compromised by increasing farm size and concentration of livestock; changing land use and development pressures (including higher taxes), traffic congestion, flooding and pollution.

Acknowledgments

Authors: Roger Nanney, U.S. Natural Resources Conservation Service, Chicago, IL, and Peter Roberts, Ontario Ministry of Agriculture, Food and Rural Affairs, Guelph, ON.

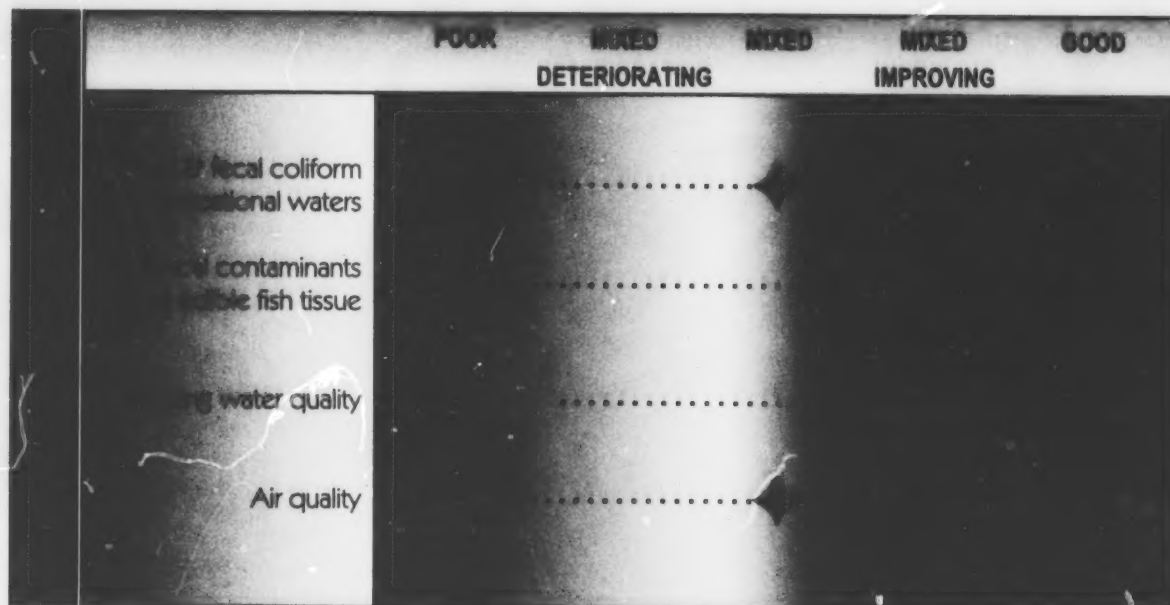


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3.5 Human Health

Human Health Indicators - Assessment at a Glance



E. coli and Fecal Coliform in Recreational Waters

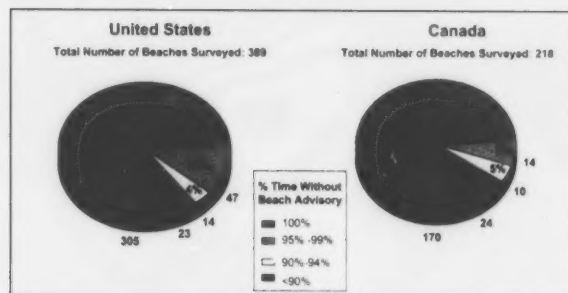
Assessment: Mixed

Purpose

This indicator assesses *E. coli* and fecal coliform contamination levels in nearshore recreational waters, acting as a surrogate indicator for other pathogen types, and it is used to infer potential harm to human health through body contact with nearshore recreational waters.

State of the Ecosystem

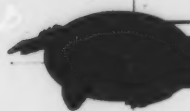
Survey reports of U.S. beach advisories during the 1998 swimming season (June, July, August) show that 78% of the reporting beaches were open for the entire 1998 season. Results were similar for Canadian beaches where 78% of the reporting beaches were open the entire season.



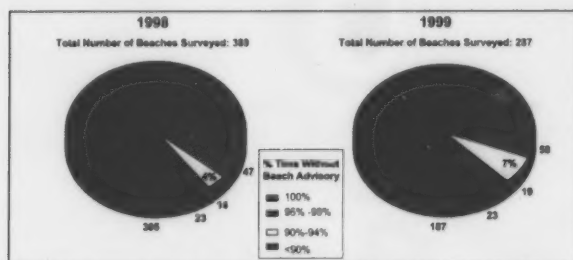
Comparison of U.S. and Canadian beach advisories for Great Lakes beaches, 1998.

Source: U.S. Environmental Protection Agency Beach Watch Program, National Health Protection Survey of Beaches for Swimming (1998) and Ontario Ministry of Environment

Survey reports of U.S. beach closings or advisories during the 1999 season show that 65% of the reporting beaches were open for the entire 1999 season. Several factors may have influenced the apparent increase in percentage of beach closings in 1999 compared with 1998:



- Fewer beach managers responded to survey questionnaires in 1999, and of those beaches that were reported, not all had been included in the 1998 data;
- More beach managers were using *E. coli* testing in 1999 than in 1998. *E. coli* is a more sensitive indicator of public health risks for swimmers, and it gives more consistent results. U.S. jurisdictions have begun to adopt uniform testing procedures for *E. coli* in the water at swimming beaches. This is an improvement over past methods and will provide more accurate information about potential risks to human health from swimming. While the actual water quality near beaches may not have changed, this new method may result in more beach advisories in the future; and
- A different accounting for the number of beach advisory days was used in 1999. For example, a two day episode of elevated bacterial levels in 1998 would have counted as one beach advisory.



U.S. beach advisories for Great Lakes beaches, 1998 vs. 1999.

Source: U.S. Environmental Protection Agency Beach Watch Program, National Health Protection Survey of Beaches for Swimming (1998)

Future Pressures

Population growth causing both increased demands made on sewage treatment plant capacities and the probability of release of untreated effluent, as well as more private treatment systems, especially in resort/vacation areas, may cause an increase of undetected releases of inadequately treated waste.

Acknowledgments

The following personnel contributed data, analysis, or reporting expertise to this indicator:

David Rockwell, Paul Bertram, and Wade Jacobson (SEE Program), U.S. Environmental Protection Agency, Great Lakes National Program Office, Chicago, Illinois. Richard Whitman, U.S. Geological Survey, Lake Michigan Ecological Research Station, Porter, Indiana. Marcia Jimenez, City of Chicago, Chicago, Illinois. Duncan Boyd and Mary Wilson, Ontario Ministry of Environment, Environmental Monitoring and Reporting

Branch, Toronto, Ontario. Peter Gauthier, City of Toronto, Environmental Health Services, Toronto, Ontario.

Chemical Contaminants in Edible Fish Tissue

Assessment: Mixed, improving

Purpose

This indicator assesses the concentration of persistent, bioaccumulating, toxic (PBT) chemicals in Great Lakes fish, and it is used to infer the potential exposure of humans to PBT chemicals through consumption of Great Lakes fish caught via sport and subsistence fishing. This will be accomplished using fish contaminant data and a standardized fish advisory protocol. The approach is illustrated using the Great Lakes protocol for PCBs as the standardized fish advisory benchmark applied to historical data to track trends in fish consumption advice.

State of the Ecosystem

Fish Consumption Advisory Programs are well established in the Great Lakes. States, tribes, and the province of Ontario have extensive fish contaminant monitoring programs and issue advice to their residents about how much fish and which fish are safe to eat. Advice from these agencies to limit consumption of fish is related to levels of PCBs, mercury, chlordane, dioxin, and toxaphene in the fish, but vary by lake.

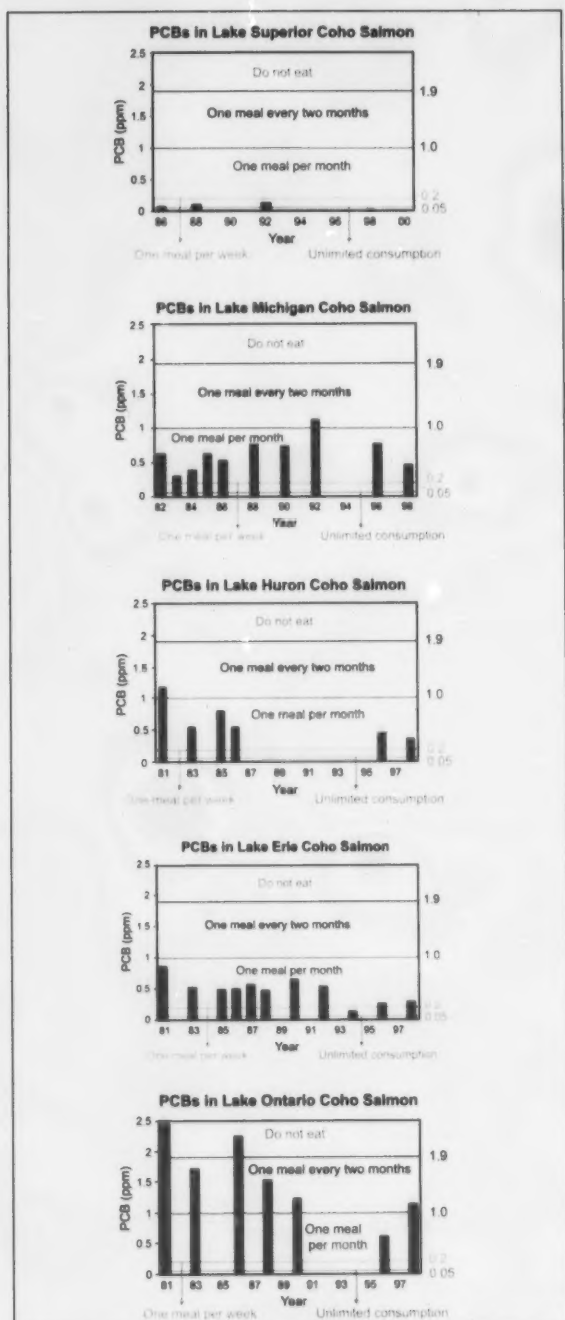
The accompanying figures illustrate the results of applying a uniform fish advisory protocol to historical data on PCBs in coho salmon fillets. The resulting advisories do not necessarily reflect actual advisories issued in each lake basin.

Future Pressures

Fish consumption advisories will still be required because of organochlorine contaminants, although these are generally decreasing. Mercury, the health effects of multiple contaminants, and endocrine disruptors are also of concern.

Acknowledgments

Authors: Patricia McCann, Minnesota Department of Health, and Sandy Hellman, U.S. Environmental Protection Agency, Great Lakes National Program Office.



Results of a uniform fish advisory protocol applied to historical data (PCBs, coho salmon) in the Great Lakes.

Source: Sandy Hellman, U.S. Environmental Protection Agency, Great Lakes National Program Office

Drinking Water Quality

Assessment: Good

Purpose

This indicator evaluates the chemical and microbiological contaminant levels in drinking water. It also assesses the potential for human exposure to drinking water contaminants and the effectiveness of policies and technologies to ensure safe drinking water.

State of the Ecosystem

There are many facets of drinking water, however this report focuses mainly on raw water from the Great Lakes proper.

At present, data from 22 sites around the basin have been assessed. The parameters used include both microbiological and chemical contaminants in raw water. Taste and odour, however, are most appropriately measured in treated water. The chemical parameters chosen were atrazine, nitrate and nitrite. These chemicals are seasonal and flow dependent. While minimal levels of atrazine, nitrate and nitrite were detected in raw water, monthly averages and maximums fell below the federal regulations for treated water. However, it should be noted that although atrazine seasonally enters the lakes by way of tributaries, this pattern was not detected at the 22 intakes included here.

Turbidity was chosen as a parameter for its correlation with potential microbial problems. High turbidity can interfere with disinfection and provide a medium for microbial growth. Turbidity values vary depending on season, location and lake. There are no raw water maximum levels for turbidity. However, by sampling raw water turbidity levels, the treatment plants can adjust treatment for optimal removal of microbial contaminants.

The level of organic matter can be determined by examining Total Organic Carbon (TOC) or Total Dissolved Organic Carbon (DOC). The DOC concentrations in raw water at the Canadian sites were fairly low, as was TOC at the majority of U.S. sites.

Taste and odour is a complex indicator. While it is an extremely important indicator to consumers, it is



U.S. and Canadian water treatment plants used in this report.

also difficult to quantitatively measure. Not all of the chosen water treatment sites had taste and odour data readily available. This indicator was evaluated for August 1999 at the six sites where data were available. Testing is done in August, since increased odour problems are usually associated with increased water temperatures. There were minimal problems with taste and odour at the six water treatment facilities that reported this parameter.

The microbiological indicators suggested are total coliform, *Escherichia coli*, *Giardia lamblia*, and *Cryptosporidium parvum*. The methods of analyzing water for *Giardia lamblia* and *Cryptosporidium parvum* are not the most reliable at this time, but it is suggested that these remain indicators as better methods become available. *Escherichia coli* is only tested when tap water tests positive for total coliform. Total coliform is probably the best choice for a microbial indicator at this time because it is the most uniformly tested. It is a required test in the U.S. and Canada. At the U.S. sites there have been no total

coliform exceedances for the last ten years. While the total coliform data were available for the Canadian sites, there presently is no user-friendly method for exceedance interpretation.

The health of the Great Lakes, as determined by these drinking water parameters at these 22 sites, is good. Chemical contaminants are consistently tested to be at minimal levels even prior to treatment. Additionally, violations of these chemical and

microbial parameters are extremely rare. The risk of human exposure to contaminants is low. The quality of drinking water as it leaves the water treatment plants meets standards. The quality of water delivered, however, can vary due to the possibility of contaminants entering the distribution system.

Future Pressures

Pressures that could compromise the quality of drinking water include land use and agricultural runoff; increases in both algal presence and water temperatures; byproducts of the drinking water disinfection process; and aging distribution systems.

Acknowledgments

This report was assembled by Molly Madden (Environmental Careers Organization), with the assistance of Rod Holme (American Water Works Association), Pat Lachmaniuk (Ontario Ministry of Environment), Tom Murphy (U.S. Environmental Protection Agency, Region 5), and Paul Bertram (U.S. Environmental Protection Agency, GLNPO). Additional thanks are due to the water treatment plant operators and managers who submitted the requested data.

Air Quality

Assessment: Mixed

Purpose

This indicator assesses the air quality in the Great Lakes ecosystem, and it is used to infer the potential impact of air quality on human health in the Great Lakes basin.

State of the Ecosystem

Overall, there has been significant progress in reducing air pollution in the Great Lakes basin. For most substances of interest, both emissions and ambient concentrations have decreased over the last ten years or more. However, progress has not been uniform and differences in weather from one year to the next complicate analysis of ambient trends. Ozone can be particularly elevated during hot summers. Drought conditions result in more fugitive dust emissions from roads and fields, increasing the ambient levels of particulate matter.

The pollutants have been divided into urban (or local) and regional pollutants for this report. Mention of the U.S. or Canada in this discussion refers to the respective portions of the Great Lakes basin. Latest published air quality data are for 1997 (Canada - Ontario) and 1999 (U.S.).

Urban/local pollutants include carbon monoxide (CO), nitrogen dioxide (NO₂), sulphur dioxide (SO₂), lead, total reduced sulphur (TRS) and particulate matter. In general, there has been significant progress with urban/local pollutants over the past decade or more, though somewhat less in recent years, with a few remaining problem districts. For example, in Canada average ambient NO₂ levels have remained relatively constant through the 1990s, however the only year without exceedances of the ambient criteria was in 1997. In the U.S., for both SO₂ and particulate matter (with diameter of 10 microns or less), there are six regions that do not meet ambient criteria. Emissions in Canada of SO₂ have increased slightly in the last two years of the period and ambient levels have only shown a slight decrease in the 1990s.

For regional pollutants, transport is a significant issue, from hundreds of kilometres to the scale of the globe. Formation from other pollutants, both natural and man-made, can also be important. There are still short periods each year during which regional pollutants

(primarily ozone and fine particulates and related pollutants - collectively called smog) reach levels of concern, essentially in southern and eastern portions of the basin. Regional pollutants include ground level ozone (O₃), fine particulate matter, and air toxics. Ozone is a problem pollutant over broad areas of the Great Lakes basin (except Lake Superior). Local circulations around the Great Lakes can exacerbate the problem: high levels are found near Lakes Huron and Erie, even in areas such as in provincial parks that are well removed from local industry, and western Michigan is strongly impacted by transport across Lake Michigan from Chicago. Fine particulate matter (diameter 2.5 microns or less) is a health concern as it can penetrate deeply into the lung. In Canada, available data indicate that many locations in Southern Ontario will exceed the recently endorsed standard of 30mg/m³ (24-hour average). In the U.S., there are not enough years of data to determine trends, but it appears that there may be many areas which do not attain the new U.S. standard. Air toxics of interest include those that have potential to harm human health (e.g. cancer), based on the toxicity and likelihood for exposure. Some ambient trends have been found: in the U.S. concentrations of benzene and toluene have shown significant decreases from 1993-1998, notably in the Lake Michigan region. Styrene has also shown a significant decrease (1996-1998).

Future Pressures

Continued population growth and associated urban sprawl are threatening to offset emission reduction efforts and better control technologies, both through increased car-travel and energy consumption. Climate change may affect the frequency of weather conditions leading to high ambient concentrations of many pollutants. Evidence exists of changes to the atmosphere as a whole. Average ground-level ozone concentrations may be increasing on a global scale.

Continuing health research is both broadening the number of toxics of potential concern, and producing evidence that some existing standards should be reconsidered. There is epidemiologic evidence of health effects from ozone or fine particulates at or below levels previously considered to be background or "natural" levels.

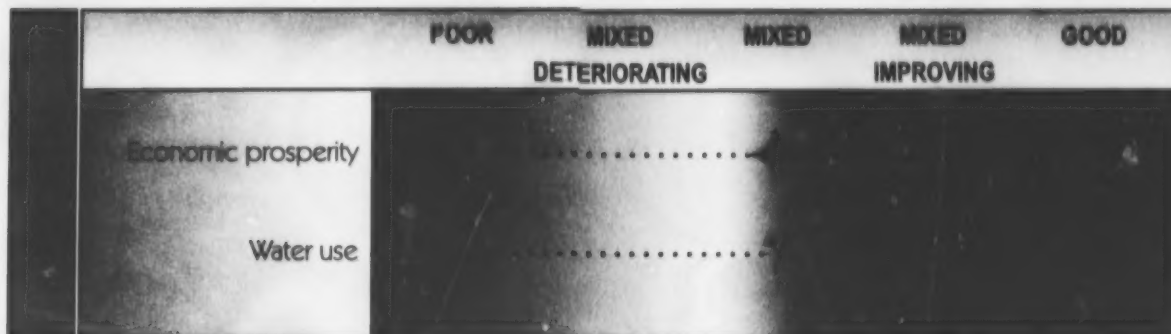
Acknowledgments

Authors: Fred Conway, Environment Canada, Meteorological Services of Canada, Downsview, ON and Joseph Chung, U.S. Environmental Protection Agency, Air Division, Chicago, IL.



3.6 Societal

Societal Indicators - Assessment at a Glance



Economic Prosperity

Assessment: Mixed

Purpose

This indicator assesses the unemployment rates within the Great Lakes basin, and, when used in association with other Societal indicators, infers the capacity for society in the Great Lakes region to make decisions that will benefit the Great Lakes ecosystem. During periods of low unemployment (i.e. economic well-being), public support for environmental initiatives by government agencies and elected officials may be increased.

State of the Ecosystem

By most measures, the binational Great Lakes regional economy is healthy. The unemployment rate for the Great Lakes states dipped below the U.S. average in 1991 and remained there during the 1990's and, for the Great Lakes states collectively, unemployment is at a 30 year low. Canadian and Ontario economic recoveries unfolded later than the U.S. but have now nearly caught up. Ontario

unemployment rates are currently at the lowest level since 1990.

Both sides of the border reflect a manufacturing intensity greater than their national economies. The Great Lakes states represent about 27% of national output in manufacturing whereas Ontario is twice as large. The manufacturing sector has many cross-border linkages particularly for the auto industry. About half of the billion dollar-a-day U.S.-Canada trade is tied to the Great Lakes states with Ontario as the most prominent province in this relationship.

Future Pressures

Good economic times translate into high levels of consumer spending and home buying. This may cause increased household and business waste generation, increased air pollution, and accelerated land use changes.

Acknowledgments

Authors: Steve Thorp, Great Lakes Commission, Ann Arbor, MI, Tom Muir, Environment Canada, Burlington, ON and Mike Zegarac, Environment Canada, Burlington, ON.

Water Use

Assessment: Unable to assess status until targets are determined

Purpose

This indicator measures the amount of water used by residents of the Great Lakes basin. It also indirectly measures the stress to the Great Lakes ecosystem caused by the extraction of this water and the generation of wastewater pollution (there is a direct relationship between the amount of water used and the quantity and quality of wastewater discharged).

State of the Ecosystem

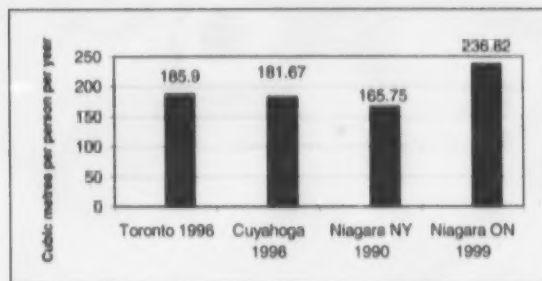
Water use was compared between four sample sites. These included two larger urban cities, Toronto, Ontario and Cuyahoga County, Ohio (which includes Cleveland) and two smaller communities, the Regional Municipality of Niagara, Ontario and Niagara County, New York. Generally, there are not great differences amongst the Great Lakes basin communities in terms of water use per capita, although the Regional Municipality of Niagara, Ontario appears to be using more per capita (by approximately 50 cubic metres each year) than the other municipalities studied. The larger urban communities of Toronto, Ontario and Cuyahoga, Ohio exhibited similar water use patterns per capita. The largely rural community of Niagara County, New York had the lowest per capita water usage rates of the sample, although a bias was possible since there were a small number of residents that were using ground water (and therefore, water use was not recorded).

Future Pressures

As Great Lakes populations grow, there will be increasing demand for water for all purposes.

Acknowledgments

Authors: Ray Rivers, Rivers Consulting, Campbellville, ON and John Barr, Burlington, ON.



Water use rates of four communities in the Great Lakes basin.

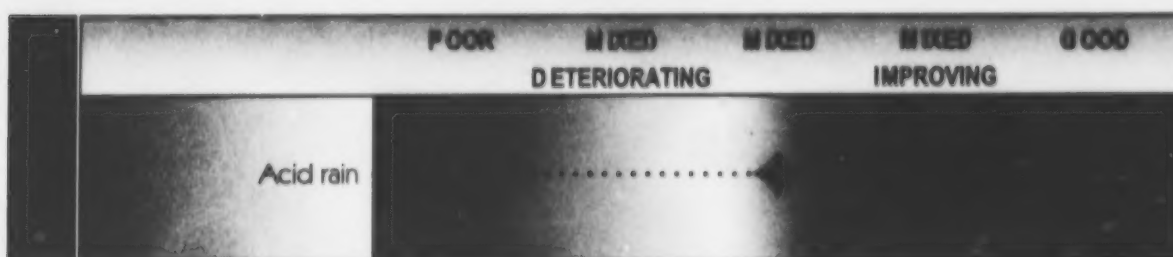
Source: Rivers Consulting and J. Barr Consulting



3.7 Unbounded

Some of the Great Lakes indicators do not fit neatly into any of the other ecological categories. These indicators may have application to more than one category or they may reflect issues that affect the Great Lakes but have global origins or implications. One such indicator, acid rain, is included here.

Unbounded Indicators -Assessment at a Glance

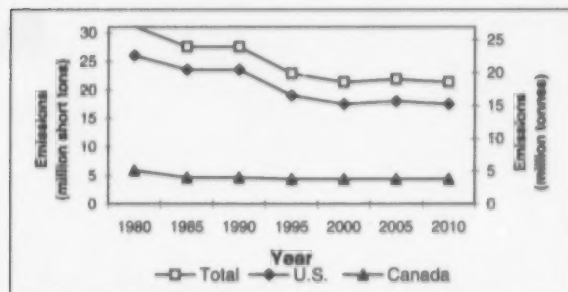


Acid Rain

Assessment: Mixed

Purpose

This indicator assesses the pH levels in precipitation and critical loadings of sulphate to the Great Lakes basin. This indicator can be used to infer the effectiveness of policies to reduce sulphur and nitrogen acidic compounds released to the atmosphere.



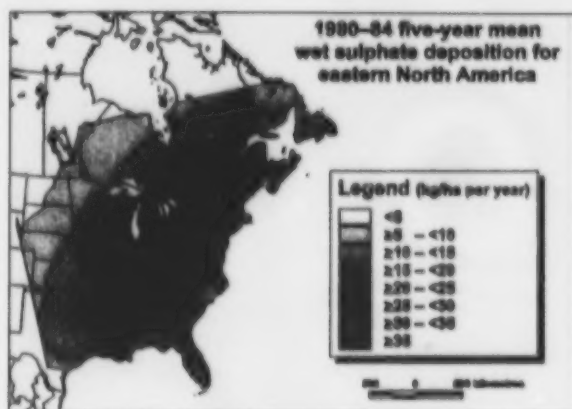
Past and predicted sulphur dioxide emissions in Canada, the U.S. and combined. Emissions after 1995 are estimates. Canadian emissions data are preliminary.

Source: Robert Vet, Meteorological Service of Canada

State of the Ecosystem

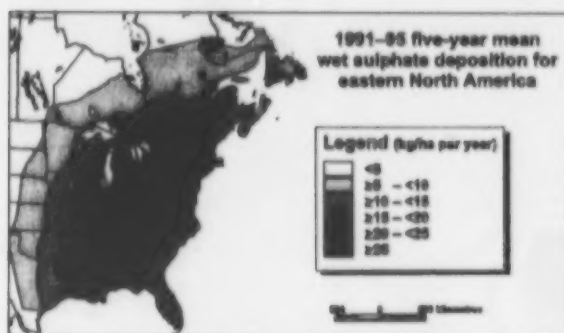
Much of the acidic precipitation in North America falls in areas around and including the Great Lakes basin. The five Great Lakes are so large that acid precipitation has little effect on them directly. Impacts mainly effect vegetation and inland lakes, especially those areas on the Canadian Shield.

SO₂ emission levels in Canada and the United States have decreased from 1980 to 1995. U.S. levels are expected to decrease by up to 40% by 2010. Canadian levels dropped 54% from 1980 to 1994 and are expected to remain at these levels. *Despite these efforts, rain is still too acidic throughout most of the Great Lakes region. Wet sulphate deposition over eastern North America has been compared between two five-year periods, 1980-84 and 1991-95. In response to the decline in SO₂ emissions, deposition decreased between the two periods. If SO₂ emissions remain relatively constant after the year 2000, as predicted, it is unlikely that sulphate deposition will change in the coming decade.*



Mean wet sulphate deposition in Eastern North America, 1980-1984.

Source: Robert Vet, Meteorological Service of Canada



Mean wet sulphate deposition in Eastern North America, 1991-1995.

Source: Robert Vet, Meteorological Service of Canada

Future Pressures

Population growth from both within and outside the basin may cause increased demands on electrical utility companies, natural resources and an increased number and use of motor vehicles.

Acknowledgments

Authors: Dean S. Jeffries, National Water Research Institute, Environment Canada, Burlington, ON and Robert Vet, Meteorological Service of Canada, Environment Canada, Downsview, ON.

3.8 Under Construction

From time to time, changes to the suite of Great Lakes indicators will be necessary in order to add, remove or revise indicators. Efforts are currently underway to develop an indicator to assess the status and potential impact of non-native species in the Great Lakes basin. Although details of this indicator have not yet been worked out, an example indicator report for aquatic exotic species is included here.

Exotic Species Introduced into the Great Lakes

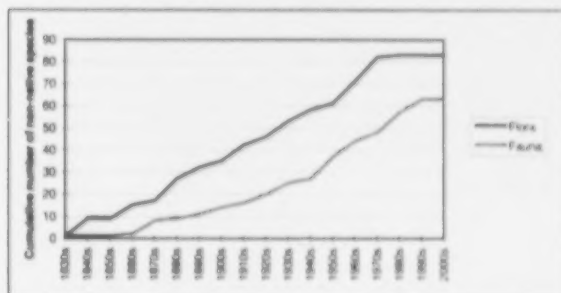
Assessment: Poor

Purpose

Currently, this indicator reports introductions of aquatic organisms not naturally occurring in the Great Lakes basin, and is used to assess the status of biotic communities in the basin. The indicator will expand to terrestrial organisms in the future.

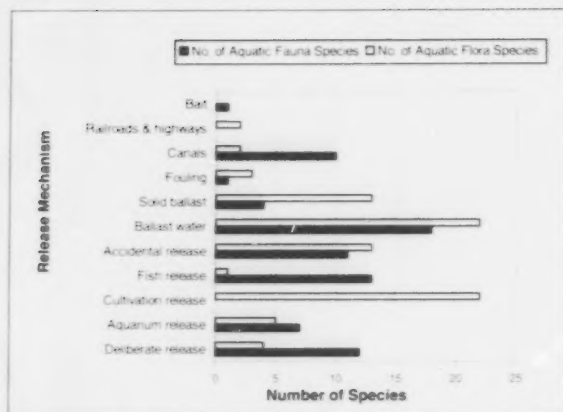
State of the Ecosystem

Since the 1830s, there have been 63 non-native aquatic animal (fauna) species introduced into the Great Lakes. Some of the main entry mechanisms include ship ballast water, the deliberate release of fish and other faunal species, and aquarium releases. In terms of aquatic plant species (flora), in almost the same timeframe there have been 83 non-native species introduced into the Great Lakes ecosystem.



Cumulative number of non-native species introduced into the Great Lakes since the 1830s.

Source: E. Mills, Cornell University, NY

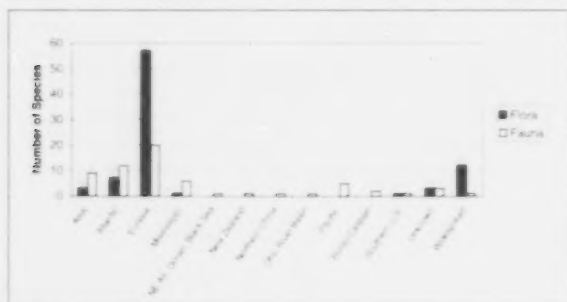


Release mechanisms for non-native species introduced into the Great Lakes.

Source: E. Mills, Cornell University, NY

The main entry mechanisms for aquatic plants include ship ballast water, cultivation release, aquarium releases, and solid ballast from ships.

Even with voluntary and mandatory ballast exchange programs recently implemented in Canada and the United States, new species associated with shipping activities have been reported and identified. It is essential that entry mechanisms be closely monitored and effective safeguards introduced and adjusted as necessary.



Regions of origin for non-native species established in the Great Lakes.

Source: E. Mills, Cornell University, NY

Future Pressures

Introductions of non-native species will continue because of increasing global trade; new diversions of water into the Great Lakes; aquaculture industries, such as fish farming, live food, and garden ponds; changes in water quality, temperature, and even the previous introduction of key species from outside (making the region potentially more hospitable for the establishment of new invaders).

Acknowledgments

Authors: Edward L. Mills, Department of Natural Resources, Cornell University, Bridgeport, NY and Margaret Dochoda, Great Lakes Fishery Commission, Ann Arbor, MI.

Section 4

Future Work on Indicators

Phase-in Approach

To begin the assessment of the state of the Great Lakes through the use of indicators, 33 summary reports were prepared for SOLEC 2000. These indicators were chosen based on the availability of data and on the cooperation of the report authors. For many of the indicators, the data were incomplete, i.e., lacking time series or geographic coverage, but an initial assessment of the ecosystem component could be made with the information available.

SOLEC organizers were pleased with the number of indicator reports that were generated, but they recognize that additional effort is needed. There is now an expectation that updates can be provided on this first set of indicators at future SOLEC events. Likewise, additional indicators are expected to be phased in at each future SOLEC until the entire suite is fully reported.

Concept of Tiers

In order to facilitate the implementation of the indicators, they have been grouped into three tiers. Tier 1 indicators are those for which at least some data are believed to exist, and an indicator report can be generated. All 33 indicators in this report are designated Tier 1, along with 10 others. Not all 43 belonging to this group have been reported on because some did not have identified authors. Additional indicator development, refinement and testing of some Tier 1 indicators will continue.

Tier 2 indicators are those for which data are not currently available, but for which an active project is underway. Activities could include establishing a monitoring program, developing the details of the indicator, or conducting research and testing of the

indicator. Most of the 10 indicators currently designated Tier 2 are included in the SOLEC Coastal Wetlands category.

An active research effort to fully develop Tier 2 indicators is called the **Great Lakes Coastal Wetlands Monitoring Consortium**. A cooperative agreement between the Great Lakes Commission and U.S. Environmental Protection Agency, Great Lakes National Program Office has been established for the first large scale, binational, collaborative effort to assess the ecological health of Great Lakes coastal wetlands. A consortium brought together by the Great Lakes Commission will:

- design and validate SOLEC indicators to assess the ecological integrity of Great Lakes coastal wetlands;
- design a long-term program to monitor Great Lakes coastal wetlands; and
- create and populate a binational coastal wetlands database accessible to all scientists, decision makers, and the public.

This consortium currently includes Great Lakes wetland scientists and resource managers from both federal governments, states/provinces, non-profit organizations, and academia. Funding for the first two years exceeds \$500,000 (U.S.), and the project may be continued for up to six years.

Tier 3 indicators are those for which data do not exist, monitoring programs need to be established, or the indicator itself needs more developmental work and/or testing. There are currently 27 of these "orphans," with representation of all SOLEC indicator categories. These indicators require deliberate attention before they can be phased into the reporting process at a future SOLEC.

U.S. Environmental Protection Agency/Great Lakes National Program Office issues an annual request for proposals for projects that help provide progress



toward the goals of the Great Lakes Water Quality Agreement. To facilitate development and testing of some of the Tier 3 indicators, projects were requested in 2001 specifically to develop, test and implement "underdeveloped" SOLEC indicators. Up to \$300,000 (U.S.) may be awarded to move Tier 3 indicators toward fully implemented, Tier 1 designation.

Commitments and Ownership

No one organization has the resources or the mandate to examine the state of all the Great Lakes ecosystem components. In collating the available information for the indicator reports, a number of difficulties became apparent while attempting to summarize different sources of information collected using different sampling and analytical methods at different locations at different times. Some differences were impossible to resolve. For the Parties to report on an on-going basis, a monitoring program with consistent protocols would have to be the primary source of the information, and a commitment to maintain such a program would be required.

Many organizations routinely collect and analyze data about some part of the ecosystem. A consensus by environmental management agencies and other interested stakeholders about what information is necessary and sufficient to characterize the state of Great Lakes ecosystem health would facilitate more efficient monitoring and reporting programs. The relative strengths of the agencies could be utilized to improve the timeliness and quality of the data collection and the availability of the information to multiple users.

For state of the Great Lakes reporting to be sustainable, commitments are required for agencies to accept lead roles to collect and interpret data and report on selected indicators prior to each SOLEC. Data for some indicators are distributed throughout several agencies. One agency, or perhaps co-lead agencies, should accept the lead role for the purpose of SOLEC reporting. The lead agency need not necessarily be the same as the one(s) conducting the monitoring, but a close association should exist between the two.

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Section 5

Biodiversity Investment Areas

Biodiversity Investment Areas (BIAs) are areas having clusters of biodiversity values, specifically, species or communities of special interest, a diversity of habitats, communities and species, and productivity and integrity. The nearshore terrestrial background paper, *Land by the Lakes, Nearshore Terrestrial Ecosystems*, prepared for SOLEC 1996, coined the phrase to signify areas of unusual biological diversity in need of protection from human impacts. For SOLEC 1998, two additional BIA papers on coastal wetlands and nearshore aquatic habitats further refined the BIA concept. At SOLEC 2000, the BIA work from previous SOLECs on nearshore terrestrial, coastal wetlands, and nearshore aquatic BIAs was integrated.

BIA integration was undertaken to begin to show the relationships amongst nearshore components of the Great Lakes. A series of 70 shoreline units were selected as a basis for the integration analysis. The coastal eco-reaches identified by the 1998 coastal wetlands BIA paper were used as a starting point. In order to fairly address all three nearshore zones (terrestrial, coastal wetlands, aquatic), three broad evaluation criteria were proposed: species or communities of special interest; diversity of habitats, communities and species; and productivity and integrity. A total of ten data sets were identified which could be used to apply the evaluation criteria to the entire Great Lakes shoreline. Data were summarized for each of the 70 shoreline units.

Tier	Composite ranking combination	Shoreline units within group	Total length of shoreline units in group (km)	% of total shoreline length
1	AAA	S1	637	3.8%
2	AAB	OS3a, OS4c, E3, E6b, HG2a, HG2b, HG3, HG7b, M1, S8c	3552	18.5%
3	AAC, ABB	E9a, HG7a, HG9, M2b, S2, S4b	2452	12.8%
4	AAD, ABC, BBB	OS1, OS2, OS3b, E7c, SC2, HG1b, HG4b, HG6, HG8a, M6b, S4c, S7c	5100	26.7%
5	ABD, ACC, BBC	OS4b, HG4a, HG10, M2a, M6c, S3b, S4a	1992	10.4%
6	All other combinations	34 units	5432	28.0%

Biodiversity Investment Area integration rankings.

Source: Ron Reid, Bobolink Enterprises, Karen Rodriguez, U.S. Environmental Protection Agency-Great Lakes National Program Office, Heather Potter and Michele DePhilip, The Nature Conservancy





Section 5

Biodiversity Investment Areas

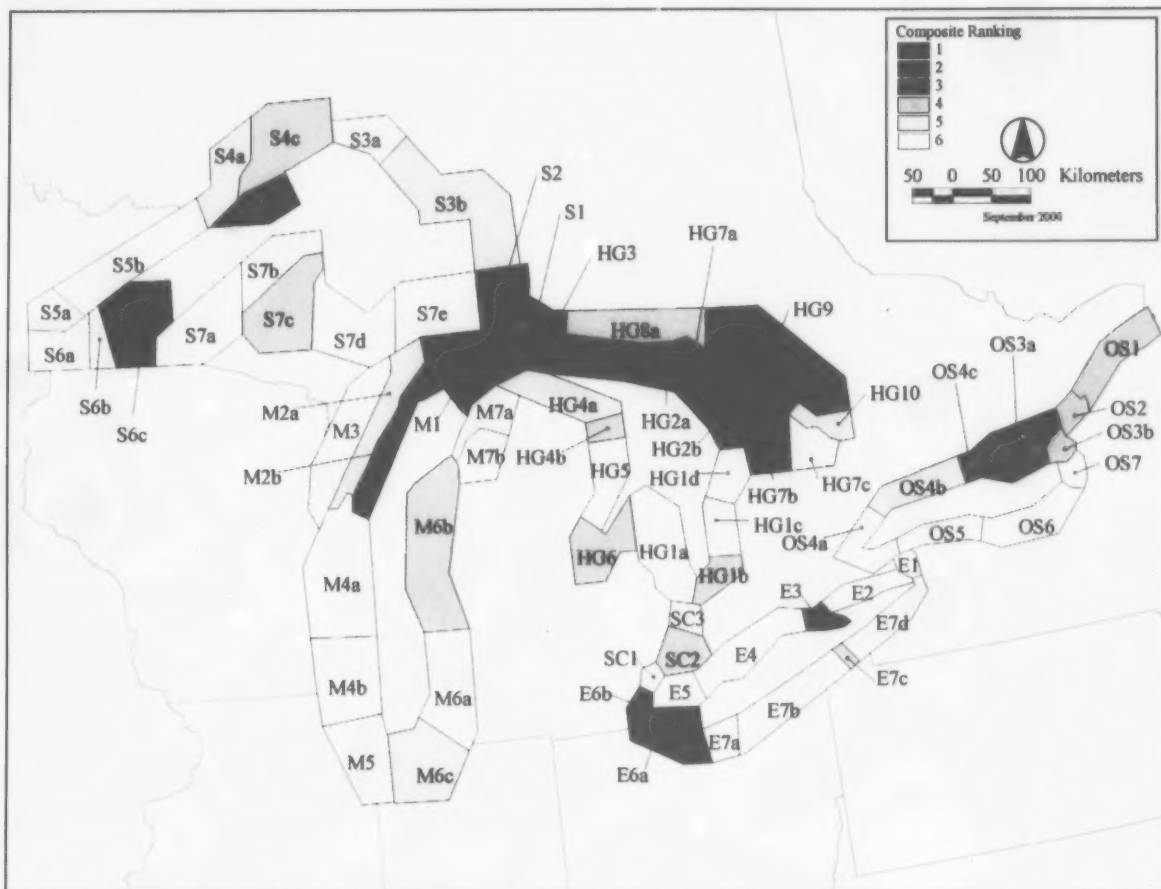
Biodiversity Investment Areas (BIAs) are areas having clusters of biodiversity values, specifically, species or communities of special interest, a diversity of habitats, communities and species, and productivity and integrity. The nearshore terrestrial background paper, *Land by the Lakes, Nearshore Terrestrial Ecosystems*, prepared for SOLEC 1996, coined the phrase to signify areas of unusual biological diversity in need of protection from human impacts. For SOLEC 1998, two additional BIA papers on coastal wetlands and nearshore aquatic habitats further refined the BIA concept. At SOLEC 2000, the BIA work from previous SOLECs on nearshore terrestrial, coastal wetlands, and nearshore aquatic BIAs was integrated.

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Tier	Composite ranking combination	Shoreline units within group	Total length of shoreline units in group (km)	% of total shoreline length
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3	AAC, ABB	E6a, HG7a, HG9, M2b, S2, S4b	2452	12.8%
4	AAD, ABC, BBB	OS1, OS2, OS3b, E7c, SC2, HG1b, HG4b, HG6, HG8a, M6b, S4c, S7c	5108	26.7%
5	ABD, ACC, BBC	OS4b, HG4a, HG10, M2a, M6c, S3b, S4a	1992	10.4%
6	All other combinations	34 units	5432	28.0%

Biodiversity Investment Area integration rankings.

Source: Ron Reid, Bobolink Enterprises, Karen Rodriguez, U.S. Environmental Protection Agency-Great Lakes National Program Office, Heather Potter and Michele DePhilip, The Nature Conservancy



Biodiversity Investment Area integration status.

Source: Ron Reid, Bobolink Enterprises, Karen Rodriguez, U.S. Environmental Protection Agency-Great Lakes National Program Office, Heather Potter and Michele DePhilip, The Nature Conservancy

An evaluation ranking was assigned for each of the three criteria for each shoreline unit. Units were then assigned to tiers based on their composite rankings for all three criteria. Shoreline units with the highest overall rankings were highlighted. Clusters of high ranking shoreline units are potential Biodiversity Investment Areas. Thus far, these potential BIAs have been named informally using nearshore terrestrial BIA names from *Land by the Lakes*, or commonly known geographic names.

The results of the rankings for each of the three criteria were compiled to produce composite rankings. The top two tiers encompass just over 22% of the shoreline length in 11 shoreline units. Their

distribution dramatically illustrates the importance of the "Mackinac-Manitoulin Arch" - the crescent of significant biodiversity sites that encompasses the northern parts of Lake Michigan, Lake Huron and Georgian Bay. In particular, the outstanding significance of the St. Marys River is noted. Adding the next tier of shoreline units brings the total shoreline encompassed by these priority units to over one-third of the Great Lakes coast, and broadens the distribution across other sections of the lakes.

The results suggest that a few of the previously identified terrestrial BIAs have only medium rankings when coastal wetland and nearshore aquatic data sets are included in the analysis. Eastern Lake

Superior, Chicago Wilderness, and Presque Isle, for example, are terrestrially significant, but did not rank high in the integrated BIA process, a conclusion not well received by those working to restore the areas. It is important to note that while in some areas, such as the southern end of Lake Michigan, a highly developed and hardened shoreline has inhibited land - water interactions, thereby posing a threat to rare terrestrial species, significant but fragmented terrestrial areas remain that need protection and restoration.

Recommendations for further BIA work include:

1. Maps for BIAs need to be updated periodically to accommodate new scientific findings as additional digital data sets are developed.
2. Data contributing to the assessment of Criterion 3, Productivity and Integrity, needs to be refined to include direct measures of current productivity or ecosystem integrity.
3. The United States data set on rare species and communities needs to be refined.
4. A more detailed review of values and potential BIA boundaries is needed, at least for the top four tiers of shoreline units.
5. Long term monitoring of ecosystem health indicators needs to be implemented both within and outside of BIAs.
6. The level of local awareness about the special qualities of BIAs needs to be raised and local support and participation in ecological restoration programs needs to be encouraged. Care must be taken to show that although an area is not as biologically rich as the Mackinac-Manitoulin Arch does not mean it is unimportant and therefore disposable.



Section 6

Conclusions

This State of the Great Lakes report represents a new way of reporting. Previously we reported on the state of the ecosystem and on the stressors to the system, but our reports lacked any predictable format or framework. The Parties to the Great Lakes Water Quality Agreement recognized that a means to report on the Great Lakes basin ecosystem in a comprehensive, consistent and understandable way was needed. The Parties have moved from a series of ad hoc indicators, reported in the State of the Great Lakes 1995 and 1997, to a refined and accepted suite of 80 indicators. These indicators will be used by the Parties and other organizations to measure the state of the Great Lakes ecosystem now and in the future.

In determining the state of the Great Lakes for this present report, only 33 of the 80 indicators were assessed. What about the others? In some cases the information is available, but the identification of an author or agency to prepare the report is all that is necessary. In other cases, more work is needed in terms of research and refinement, and monitoring programs may need to be initiated in order to implement these indicators.

The results of those indicator assessments have been summarized within each of the six major groups - human health, open and nearshore waters, coastal wetlands, land and land use, societal, and unbounded, along with a summary of the conditions in each Lake and the interconnecting channels.

Human Health

Surface waters of the Great Lakes are still amongst the best sources of drinking water in the world, and they continue to serve a large part of the 33 million people who live in the Great Lakes basin. Protection of water at its source, prior to any treatment, is still one of the best means to assure safe drinking water,

not to mention maintenance of a healthy aquatic ecosystem. Advisories related to humans eating fish are still in place on all the Great Lakes, even though chemical contamination is decreasing in most species. Contaminant levels will need to continue to decline for many more years before advisories can be lifted, or, in some areas/cases, even modified. New procedures to standardize testing for *E. coli* will help to improve swimming advisories and help beach operators to better protect human health.

Open and Nearshore Waters

Invasive, non-native aquatic species are the greatest biological threat to Great Lakes aquatic ecosystems. Despite the decline in toxic contamination in many species of Great Lakes fish, as just noted, fish populations continue to be stressed by other causes. These stresses include: weakening of the forage base, food chain disruptions, habitat loss, and competition with, or replacement by, non-native species. Sea lamprey controls since the 1960s, have allowed the rehabilitation of the Great Lakes fishery. However, evidence presented in this report shows that populations of sea lamprey in Northern Lake Huron and the St. Marys River continue to be a problem for fish populations in those areas. The process of habitat improvement through projects such as dam removal and sediment clean-up, as a part of the overall reduction in contaminants, has resulted in increased prey availability for the lamprey as well as increased lamprey spawning habitat. This has created continued dependence on controls well into the future. Suspension of such controls will have an adverse effect on the fisheries.



Coastal Wetlands

Four of the five indicators for this assessment category show that coastal wetlands continue to decline in both quantity and quality. Over two-thirds of the Great Lakes wetlands have already been lost and many of those remaining are threatened by pressures such as development, drainage, and pollution.

Land and Land Use

Urban sprawl is the greatest physical threat to high quality natural areas, rare species, farmland, and open space in the Great Lakes basin. The Great Lakes coastline still retains significant, important, and diverse natural areas such as northern Lakes Michigan and Huron, Georgian Bay, and the St. Marys River. These areas are extraordinarily biologically diverse and deserve special protection.

Societal

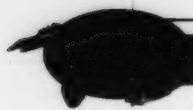
This category of indicators requires considerable work. Stewardship of Great Lakes natural resources is widespread throughout the basin and includes urban ecological restoration, rural conservation of open space, and Aboriginal preservation of species of cultural significance.

Unbounded / Under Construction

Indicators for both terrestrial and aquatic environments identify invasive, non-native aquatic species as the greatest biological threat to the Great Lakes aquatic ecosystem. Further work is required to document the impact of terrestrial non-native species and their subsequent impacts to the ecosystem.

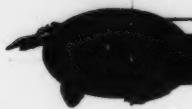
Lake by Lake Assessments

Assessments for the state of the five Great Lakes and Interconnecting Channels show **generally** that conditions are *mixed*, with some ecosystem components assessed as good, and others assessed as poor.



Chemical Acronyms/Terms Used in This Report

α - and γ -HCH	Hexachloro-cyclohexane - a manufactured chemical that does not occur naturally in the environment. It exists in eight chemical forms (called isomers). One of these forms, γ (gamma)-HCH (also known as lindane) was used as an insecticide on fruit and vegetable crops (including greenhouse vegetables and tobacco) and forest crops (including Christmas trees). It is still used in ointments to treat head and body lice, and scabies. It is also known as BHC (benzene hexachloride).
$\mu\text{g}/\text{m}^3$	Microgram per cubic metre - unit of measure.
atrazine	A common herbicide used on agricultural crops, especially corn.
BaP	Benzo-[a]-pyrene - one type of PAH (see definition).
DDE	Dichlorodiphenyl-dichloroethylene - a degradation product of DDT.
DDT	Dichlorodiphenyl-trichloroethane - the first organochlorine pesticide developed (1939). It is persistent in the environment and has been linked to numerous ecosystem effects. It has been banned from use in Canada and the United States.
dieldrin	Dieldrin was a popular pesticide for crops such as corn and cotton from 1950-1970. Concerns about damage to the environment and the potential harm to human health led EPA to ban all uses of dieldrin in 1974 except to control termites. In 1987, EPA banned all uses.
HCB	Hexachlorobenzene is released primarily as a byproduct of industrial and combustion processes. It was used as an industrial chemical and is currently present as an impurity in pesticides. Hexachlorobenzene is considered to be a persistent, bioaccumulative toxic substance (PBT). PBTS have serious potential human health and/or environmental effects.
heptachlor epoxide	Heptachlor was used extensively in the past for killing insects in homes, buildings, and on food crops, especially corn. Use slowed in the 1970s and stopped in 1988. Heptachlor epoxide is a degradation product of heptachlor and is more commonly found in the environment.
mirex	Mirex was used to control fire ants, and as a flame retardant in plastics, rubber, paint, paper, and electrical goods from 1959 to 1972. It has not been manufactured since 1978.
nitrate and nitrite	Inorganic chemicals occurring naturally as part of the nitrogen cycle. Nitrate is also used or found in fertilizers as potassium or sodium nitrate.
ng/L	Nanogram per litre - unit of measure.



OCS	Octachlorostyrene - not commercially manufactured, but has been reported to be an inadvertent by-product of certain chemical processes. OCS may also result from various incineration processes. OCS is persistent (i.e., it is resistant to chemical and/or metabolic degradation), has high bioaccumulation potential (i.e., increase in concentration in the upper levels of an aquatic food web) and is toxic.
PAH	Poly-aromatic hydrocarbons - a class of over 100 very stable organic molecules; they are highly carcinogenic but are also very common; they are a standard product of combustion, and are usually found as a mixture of 2 or more.
PCB	Polychlorinated biphenyls - a class of manufactured organic chemicals that contain 209 individual chemicals (known as congeners); there are no known natural sources of PCBs. PCBs contain one or more atoms of chlorine, are resistant to high temperatures, and do not break down in the environment.
PCDD / PCDF	Polychlorinated dibenzo-p-dioxins / polychlorinated dibenzofurans - a group of unwanted by-products of many chemical, industrial and combustion processes. Also found as impurities in some pesticides.
ppm	Parts per million - unit of measure.
toxaphene	An insecticide containing over 670 chemicals; used primarily in the southern United States to control insect pests on cotton and other crops; it was also used to control insect pests on livestock and to kill unwanted fish in lakes. Toxaphene was one of the most heavily used insecticides in the United States until 1982, when it was banned for most uses; all uses were banned in 1990.

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Environment Canada

Nancy Stadler-Salt, lead
Harvey Shear
Stacey Cherwaty

United States Environmental Protection Agency

Paul Bertram, lead
Paul Horvatin
Karen Rodriguez

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Over 50 governmental and non-governmental sectors were represented by the contributions. We recognize the participation of the following organizations. Those represented by two or more internal organizational units are denoted by *. While we have tried to be thorough, any misrepresentation or oversight is entirely unintentional, and we sincerely regret any omissions.

Federal

***Environment Canada**

Canadian Wildlife Service
Ecosystem Science Directorate
Environmental Conservation Branch
Environmental Emergencies Section
Meteorological Service of Canada
National Water Research Institute

Fisheries and Oceans Canada

National Oceanic and Atmospheric Administration

U.S. Department of Agriculture - Natural Resources Conservation Service

U.S. Environmental Protection Agency

Great Lakes National Program Office
Region 2

*Region 5

***U.S. Fish and Wildlife Service**

Green Bay Fishery Resources Office

***U.S. Geological Survey - Biological Resources Division**

Great Lakes Science Center

Lake Ontario Biological Station

Lake Superior Biological Station

Lake Michigan Ecological Research Station



Provincial and State

Indiana Geological Survey
Michigan Department of Natural Resources
Minnesota Department of Health
*New York Department of Environmental Conservation
*Ontario Ministry of Environment
Ontario Ministry of Natural Resources
Ontario Ministry of Agriculture, Foods, and Rural Affairs
Ohio Division of Wildlife
Ohio Division of Natural Resources
Pennsylvania Department of Environmental Protection
Wisconsin Department of Natural Resources

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City of Chicago
City of Toronto

Aboriginal

Bad River Tribe
Chippewa Ottawa Treaty Fishery Management Authority
Mohawk Council of Akwesasne

Academic

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Cornell University, NY
Indiana University, IN
James Madison University, VA
Michigan State University, MI
York University, ON

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Great Lakes Commission
Great Lakes Fishery Commission
International Joint Commission

Environmental Non-Government Organizations

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The Nature Conservancy

Industry

American Water Works Association
Council of Great Lakes Industries
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Bobolink Enterprises
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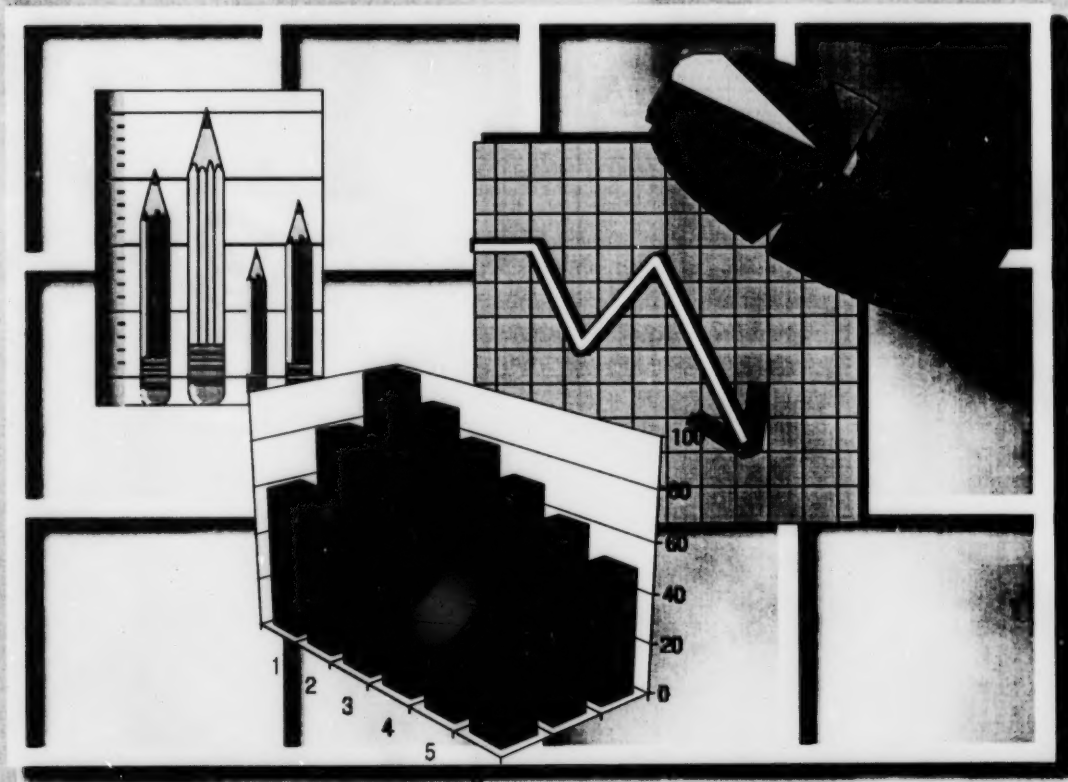


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The ABC's Of Indicators



A PRIMER ON DEVELOPING AND USING INDICATORS

Assessing Progress

The Great Lakes Water Quality Agreement (GLWQA) sets out the commitment of the United States and Canada to "restore and maintain the chemical, physical and biological integrity of the waters of the Great Lakes basin ecosystem". The governments have been working towards achieving this vision over the past 25 years. The first GLWQA was signed in 1972 and focused on control of nutrients. In 1978, the GLWQA was renegotiated, with a focus on persistent toxic chemicals. The terms "virtual elimination" and "zero discharge" entered the vocabulary of Great Lakes managers, scientists, and citizens, as a lofty goal towards which we all need to strive. Finally in 1987, the 1978 GLWQA was amended, and called for the development of indicators of ecosystem health.

Billions of dollars have been invested by the two countries to improve the health of the Great Lakes and to strive towards the Agreement's goals. Policies, regulations and programs have been developed to address the complex problems facing the Lakes,

including: nutrient pollution, persistent toxic chemicals, habitat destruction, loss of native species and introduction of exotic ones, shoreline alterations, atmospheric deposition of pollutants, and many others.

What is needed is an easily understood way of reporting on progress. A comprehensive set of Great Lakes indicators will help assess progress towards the binational commitment in the GLWQA, and determine how much farther we have to go to meet the goals of the Agreement.



health. It gives a clue about the "bigger picture" by looking at a small piece of the puzzle, or at several pieces together.

To a sailor or a pilot, for example, atmospheric pressure is an indicator of the weather. To a doctor, blood pressure provides a clue about the overall health of a patient. To an economist, Gross Domestic Product (GDP) gives a snapshot of the state of a country's economy.

Each of these indicators provides information about conditions at a particular point in time. To be really useful, however, we need indicators to give us information about trends over time. Is the barometric pressure rising, falling or staying the same? Is our blood pressure higher or lower than it was the last time we visited the doctor? Is the GDP growing or shrinking?

What is an indicator?

An indicator is a piece of evidence or signal that tells us something about the conditions around us. It is a tool which provides information about the state of large systems – such as the environment, the economy, the weather, or even human

One of the best ways to track trends in the condition of a *system* is through the development and use of a set or "suite" of indicators. By looking at a number of indicators together, we can see which way a *system* is going: up or down, forward or backward. We can then assess whether it is getting better or worse or staying the same.

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Why do we need indicators for the Great Lakes basin ecosystem?

Simply put, we need Great Lakes indicators because it is only through a comprehensive set of environmental indicators that we can get a "big picture" perspective on the state of the entire system.

Assessing the health of something as big and complex as the Great Lakes basin ecosystem, which contains one fifth of the world's fresh water, 10,000 miles (16,000 kilometres) of shoreline, and 33.5 million residents, is a significant challenge. No one organization has the resources or the mandate to examine the state of the entire system. However, dozens of organizations and thousands of individuals routinely collect data, analyze it, and report on parts of the ecosystem.

Developing a set of Great Lakes indicators will enable the Great Lakes community – government and non-government organizations, industry and individual citizens – to work together within a consistent framework to assess and monitor changes in the state of the Great Lakes basin ecosystem.

How will Great Lakes indicators be used?

Through the development and use of a set of indicators for the Great Lakes basin ecosystem, we can:

- assess changes in the state of the ecosystem and progress towards achieving the goals of the GLWQA;
- understand better how our actions affect the ecosystem, and determine the types of programs, policies or regulations needed to address the environmental impacts;
- gain a clearer understanding of existing (and emerging) environmental problems and their solutions;
- provide information that will help managers better assess the success of current programs and provide a rationale for future ones; and
- provide information that will help set priorities for research, data collection, monitoring and clean-up programs.

GLOSSARY

Goal: A condition or state desired to be brought about through a course of action or program. Goals are usually qualitative statements that provide direction for plans and projects. Goals are not specific numerical limitations, but conditions or states which can be obtained through careful planning and implementation.

Indicator: In the context of SOLEC, it is a measurable feature (or features) that provides outcome-oriented, managerially and scientifically useful evidence of environmental and ecosystem quality or reliable evidence of trends in quality.

Lakewide Management Plans (LaMPs): A comprehensive strategy developed jointly by the United States and Canada to restore and protect

beneficial uses in the open waters of each Great Lake.

Objective: Specific descriptions of the state or condition that must be met in order to achieve goals and vision.

Remedial Action Plans (RAPs): Plans that embody a systematic and comprehensive ecosystem approach to restoring and protecting beneficial uses in Areas of Concern throughout the Great Lakes ecosystem basin.

Target (or endpoint): Specific, attainable, quantitative endpoints for indicators that determine achievement of objectives.

Vision: A general description of the desired state of a lake, geographical area, or region that is expressed by a group of stakeholders. A vision statement provides a description of a desired state – it provides direction and establishes a horizon to be sought.

FOR THE GREAT LAKES BASIN ECOSYSTEM

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Through the development and use of a set of indicators for the Great Lakes basin ecosystem, we can:

- assess changes in the state of the ecosystem and progress towards achieving the goals of the GLWQA;
- understand better how our actions affect the ecosystem, and determine the types of programs, policies or regulations needed to address the environmental impacts;
- gain a clearer understanding of existing (and emerging) environmental problems and their solutions;
- provide information that will help managers better assess the success of current programs and provide a rationale for future ones; and
- provide information that will help set priorities for research, data collection, monitoring and clean-up programs.

GLOSSARY

Goal: A condition or state desired to be brought about through a course of action or program. Goals are usually qualitative statements that provide direction for plans and projects. Goals are not specific numerical limitations, but conditions or states which can be obtained through careful planning and implementation.

Indicator: In the context of SOLEC, it is a measurable feature (or features) that provides outcome-oriented, managerially and scientifically useful evidence of environmental and ecosystem quality or reliable evidence of trends in quality.

Lakewide Management Plans (LaMPs): A comprehensive strategy developed jointly by the United States and Canada to restore and protect

beneficial uses in the open waters of each Great Lake.

Objective: Specific descriptions of the state or condition that must be met in order to achieve goals and vision.

Remedial Action Plans (RAPs): Plans that embody a systematic and comprehensive ecosystem approach to restoring and protecting beneficial uses in Areas of Concern throughout the Great Lakes ecosystem basin.

Target (or endpoint): Specific, attainable, quantitative endpoints for indicators that determine achievement of objectives.

Vision: A general description of the desired state of a lake, geographical area, or region that is expressed by a group of stakeholders. A vision statement provides a description of a desired state – it provides direction and establishes a horizon to be sought.

An Example of a Great Lakes Indicator

In order to understand how we use indicators, it is important to see how indicators fit into the hierarchy of a vision, goals, objectives and targets for the ecosystem.

The GLWQA sets an overall **vision** that we will "restore and maintain the chemical, physical and biological integrity of the waters of the Great Lakes basin ecosystem." The Agreement also sets a **goal** (called a General Objective) that the waters should be "free from nutrients...in

The indicator, phosphorus concentration in the waters, tells us something about the Lakes in relation to the objective. Scientists have estimated that if Lake Erie received 11,000 tonnes of phosphorus per year, the concentration of phosphorus in the Lake's central basin would be measurable at about 10 parts per billion. This concentration, then, is the **target** or **end point** for the indicator. It provides a frame of reference to evaluate the **measurement** of phosphorus concentrations. Therefore, knowledge of the concentration of phosphorus in the waters of the Great Lakes can help us assess progress towards achieving the GLQWA vision, goals and objectives.



What are the main considerations in selecting Great Lakes indicators?

One potential indicator to assess the health of the nearshore and open water areas of the Great Lakes is the concentration of phosphorus in the water. High levels of phosphorus can accelerate the natural aging of a lake, lead to nuisance blooms of algae, depletion of oxygen in water, and other problems.

amounts that create growths of aquatic life that interfere with beneficial uses." Annex 3 of the Agreement lists specific **objectives** for the annual loading of phosphorus to each of the Great Lakes (e.g. 11,000 tonnes for Lake Erie). If the annual loadings are no more than these specified amounts, the Lakes would be expected to be free of nuisance growths of algae.

When we are looking for indicators to give us information on complex systems – such as the Great Lakes basin ecosystem – there are several key considerations.

The most important of these are identifying a model or framework for indicator development, keeping an "ecosystem perspective", and establishing criteria for indicator selection.

Model for Indicator Development

One model for developing environmental indicators is the "State-Pressure-Activities" model. The underlying concept for this model is that human actions create pressures on the environment around us, leading to changes in the state or conditions in the environment, which in turn leads us to respond with various activities to reduce the impacts of our actions. Using the model as a starting point, indicators are developed for each of the three components:

State: Indicators can help us assess the state of the environment by providing information to answer questions that concern us such as: Can we eat the fish? Can we swim at the beaches? Can we drink the water? Is the ecosystem healthy and functioning as we would expect?

Pressure: Human actions – how we build, how we alter or degrade the environment, the resources we consume – can have a dramatic, and sometimes irreversible effect on the state of the environment. For this reason, we use indicators to give us information about the

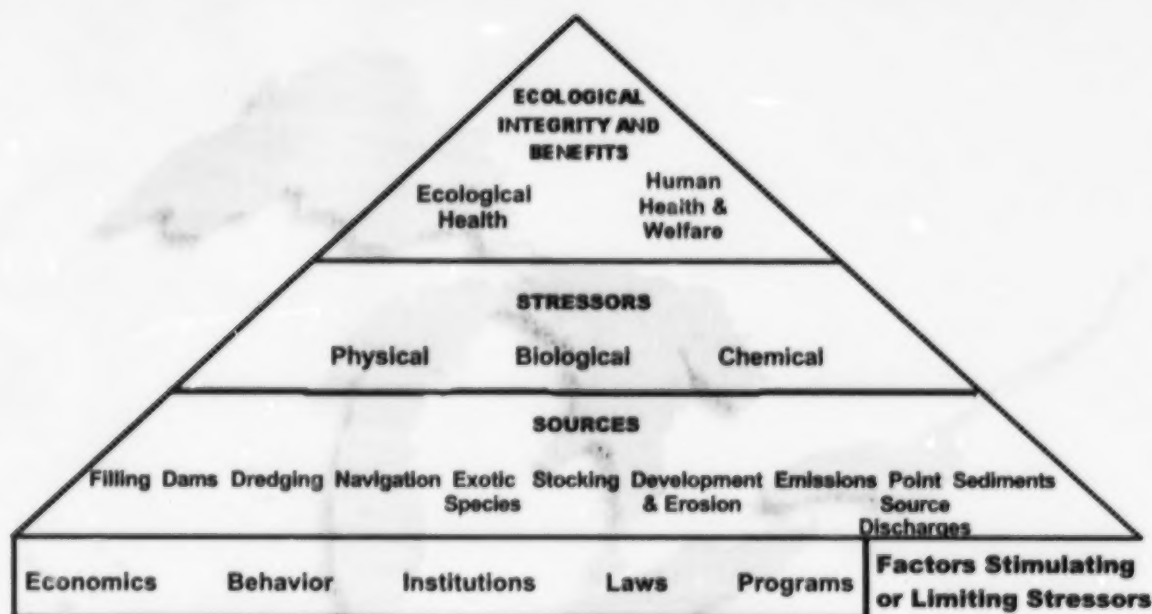
pressures we put on the environment through our actions. Some common examples of these pressures are the amount of pollutants discharged to the environment, the rate of urbanization, the presence of exotic species such as zebra mussels, and the amount of wetlands filled in.

Activities: Indicators that address societal responses give us valuable information about what we are doing to prevent, reduce or eliminate the stresses, and whether we are achieving what we set out to do. Are sewage treatment plants meeting the targets laid down in regulations? Have we met local targets for restoring wildlife habitat? Are we teaching young people about the environment through our schools? Have municipalities adopted and implemented sediment control programs to reduce erosion from construction sites?

Keeping an "Ecosystem Perspective"

In addition to the "State-Pressure-Activities" model, it is important to keep an ecosystem perspective in developing indicators. One way of doing this is to view the ecosystem in layers, with human and aquatic health at the top as the highest level of ecosystem integrity. The second layer is the chemical, physical and biological environment, including the various stresses – such as chemical pollutants and exotic species – that affect the environment. The third layer consists of human activities which are the sources of the stresses. Programs to address the sources can be seen as part of this layer, or as an underlying fourth layer. In developing indicators, it is important that a full representative spectrum of indicators be selected to examine the state of all layers of the ecosystem.





Indicator Selection Criteria

A third key consideration in selecting indicators is the development of a list of factors or criteria that will be used to select the most appropriate indicators. Important factors that could be used to select a set of indicators for the Great Lakes basin ecosystem include:

Necessary: Are the indicators *necessary* to give us the information we need to assess the state of the ecosystem;

Sufficient: Will the indicators provide *sufficient* information to give a picture of the overall health of the ecosystem; and

Feasible: Is it *feasible* (economically and in terms of human resources) to collect measurement information needed for the indicators.

Other criteria which can be used to select indicators include: scientific validity, understandability, relevance, representativeness, interpretability, data availability, timeliness and cost considerations.

These criteria provide an effective basis for comparing various candidate indicators that could be included as part of the set of Great Lakes indicators. Those indicators that rate highly for all or most of the factors would be the best candidates for inclusion in the set.

FOR THE GREAT LAKES BASIN ECOSYSTEM

Why is it important to get agreement on indicators?

When agreement is reached on a common set of indicators for the Great Lakes basin ecosystem, a number of important benefits will follow. The set will:

- help focus government agencies' efforts related to Great Lakes data collection, research, monitoring and reporting, thus improving the allocation of government resources, and harmonizing activities;
- improve the quality of data and the ability to share information through the use of consistent protocols and common databases;
- create a better foundation for environmental managers and resource planners to assess

progress towards environmental management objectives, and to create programs, policies and regulations to meet these objectives; and

- provide the Great Lakes community, including the general public, with more consistent and effective reporting on the state of the Great Lakes and on progress towards achieving the goals of the GLWQA.

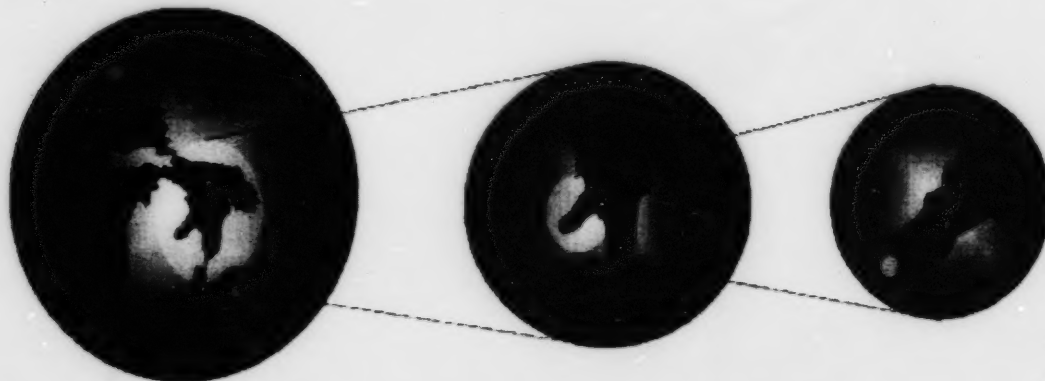
What is the role of SOLEC in developing Great Lakes indicators?

The State of the Lakes Ecosystem Conference (SOLEC) was created by the United States and Canada to report every two years on the state of the Great Lakes basin ecosystem, and on progress made toward reaching the goals of the GLWQA. Through SOLEC, the governments of the United States and Canada are striving to establish a

consistent, easily understood set of candidate indicators that will enable effective reporting on the state of the Great Lakes and on progress toward GLWQA goals at the basin-wide scale.

These candidate indicators will be the subject of extensive review and discussion at SOLEC 98. Following the conference, a revised list of candidate indicators will be included as part of the binational State of the Lakes report, scheduled for release in the summer of 1999.

The SOLEC indicators will complement and build on the work done through Lakewide Management Plans (LaMPs) and Remedial Action Plans (RAPs) to develop indicators at the lake and local levels respectively. Similarly, SOLEC will draw upon the extensive work done by others, including the International Joint Commission and the Great Lakes Fishery Commission.



WHAT IS THE GREAT LAKES WATER QUALITY AGREEMENT?

The Agreement, first signed in 1972 and renewed in 1978, expresses the commitment of each country to restore and maintain the chemical, physical and biological integrity of the Great Lakes Basin Ecosystem and includes a number of objectives and guidelines to achieve these goals. It reaffirms the rights and obligation of Canada and the United States under the Boundary Waters Treaty and has become a major focus of Commission activity.

In 1987, a Protocol was signed amending the 1978 Agreement. The amendments aim to strengthen the programs, practices and technology described in the 1978 Agreement and to increase accountability for their implementation. Timetables are set for implementation of specific programs.

The Parties will meet biennially to discuss progress and report periodically to the Commission. New annexes address atmospheric deposition of toxic pollutants, contaminated sediments, groundwater, and nonpoint sources of pollution. Annexes are also added to incorporate the development and implementation of remedial action plans for Areas of Concern and lakewide management plans to control critical pollutants.

The Commission monitors and assesses progress under the Agreement and advises Governments on matters related to the quality of the boundary waters of the Great Lakes system. The Agreement also calls upon the Commission to assist the Governments with joint programs under the Agreement, and provides for two binational boards -- the Great Lakes Water Quality Board and the Great Lakes Science Advisory Board -- to advise the Commission.

Revised

Great Lakes Water Quality Agreement of 1978

Agreement, with Annexes and Terms of Reference, between the United States and Canada signed at Ottawa November 22, 1978

and

Phosphorus Load Reduction Supplement signed October 16, 1983

as amended by Protocol signed November 18, 1987

Office Consolidation

INTERNATIONAL JOINT COMMISSION UNITED STATES AND CANADA

September, 1989

PROTOCOL AMENDING THE 1978 AGREEMENT BETWEEN THE UNITED STATES OF AMERICA AND CANADA ON GREAT LAKES WATER QUALITY, AS AMENDED ON OCTOBER 16, 1983

AGREEMENT BETWEEN CANADA AND THE UNITED STATES OF AMERICA ON GREAT LAKES QUALITY, 1978

ARTICLE	SUBJECT
I	Definitions
II	Purpose
III	General Objectives
IV	Specific Objectives
V	Standards, Other Regulatory Requirements, and Research
VI	Programs and Other Measures
VII	Powers, Responsibilities and Functions of the IJC
VIII	Joint Institutions and Regional Office
IX	Submission and Exchange of Information
X	Consultation and Review
XI	Implementation
XII	Existing Rights and Obligations
XIII	Amendment
XIV	Entry Into Force and Termination
XV	Supersession

ANNEX	SUBJECT
1	Specific Objectives
	Specific Objectives Supplement to Annex 1
2	Remedial Action Plans and Lakewide Management Plans
3	Control of Phosphorus
	Phosphorus Load Reduction Supplement
4	Discharges of Oil and Hazardous Polluting Substances from Vessels
5	Discharges of Vessel Wastes
6	Review of Pollution from Shipping Sources
7	Dredging
8	Discharges from Onshore and Offshore Facilities
9	Joint Contingency Plan
10	Hazardous Polluting Substances
	Appendix 1 - Hazardous Polluting Substances
	Appendix 2 - Potential Hazardous Polluting Substances
11	Surveillance and Monitoring
12	Persistent Toxic Substances
13	Pollution from Non-Point Sources
14	Contaminated Sediment
15	Airborne Toxic Substances
16	Pollution from Contaminated Groundwater
17	Research and Development
	Terms of Reference for the Joint Institutions and the Great Lakes Regional Office

PROTOCOL AMENDING THE 1978 AGREEMENT BETWEEN THE UNITED STATES OF AMERICA AND CANADA ON GREAT LAKES WATER QUALITY, AS AMENDED ON OCTOBER 16, 1983

The Government of the United States of America and the Government of Canada,

REAFFIRMING their commitment to achieving the purpose and objectives of the 1978 Agreement between the United States of America and Canada on Great Lakes Water Quality, as amended on October 16, 1983;

HAVING developed and implemented cooperative programs and measures to achieve such purpose and objectives;

RECOGNIZING the need for strengthened efforts to address the continuing contamination of the Great Lakes Basin Ecosystem, particularly by persistent toxic substances;

ACKNOWLEDGING that many of these toxic substances enter the Great Lakes System from air,

from ground water infiltration, from sediments in the Lakes and from the runoff of non-point sources;

AWARE that further research and program development is now required to enable effective actions to be taken to address the continuing contamination of the Great Lakes;

DETERMINED to improve management processes for achieving Agreement objectives and to demonstrate firm leadership in the implementation of control measures;

Have agreed as follows:

AGREEMENT BETWEEN CANADA AND THE UNITED STATES OF AMERICA ON GREAT LAKES QUALITY, 1978

The Government of Canada and the Government of the United States of America,

HAVING in 1972 and 1978 entered into Agreements on Great Lakes Water Quality;

REAFFIRMING their determination to restore and enhance water quality in the Great Lakes System;

CONTINUING to be concerned about the impairment of water quality on each side of the boundary to an extent that is causing injury to health and property on the other side, as described by the International Joint Commission;

REAFFIRMING their intent to prevent further pollution of the Great Lakes Basin Ecosystem owing to continuing population growth, resource development and increasing use of water;

REAFFIRMING in a spirit of friendship and cooperation the rights and obligations of both countries under the Boundary Waters Treaty, signed on January 11, 1909, and in particular their obligation not to pollute boundary waters;

CONTINUING to recognize that right of each country in the use of the Great Lakes waters;

HAVING decided that the Great Lakes Water Quality Agreements of 1972 and 1978 and subsequent reports of the International Joint Commission provide a sound basis for new and more effective cooperative actions to restore and enhance water quality in the Great Lakes Basin Ecosystem;

RECOGNIZING that restoration and enhancement of the boundary waters cannot be achieved independently of other parts of the Great Lakes Basin Ecosystem with which these waters interact;

CONCLUDING that the best means to preserve the aquatic ecosystem and achieve improved water quality throughout the Great Lakes System is by adopting common objectives, developing and implementing cooperative programs and other measures, and assigning special responsibilities and

functions to the International Joint Commission;

Have agreed as follows:

ARTICLE 1 - DEFINITIONS

As used in this Agreement:

(a)"Agreement" means the present Agreement as distinguished from the Great Lakes Water Quality Agreement of April 15, 1972;

(b)"Annex" means any of the Annexes to this Agreement, each of which is attached to and forms and integral part of this Agreement;

(c)"Boundary waters of the Great Lakes System" or "boundary waters" means boundary waters, as defined in the Boundary Waters Treaty, that are within the Great Lakes System;

(d)"Boundary Waters Treaty" means the Treaty between the United States and Great Britain Relating to Boundary Waters, and Questions Arising Between the United States and Canada, signed at Washington on January 11, 1909;

(e)"Compatible regulations" means regulations no less restrictive than the agreed principles set out in this Agreement;

(f)"General Objectives" are broad descriptions of water quality conditions consistent with the protection of the beneficial uses and the level of environmental quality which the Parties desire to secure and which will provide overall water management guidance;

(g)"Great Lakes Basin Ecosystem" means the interacting components of air, land, water and living organisms, including humans, within the drainage basin of the St. Lawrence River at or upstream from the point at which this river becomes the international boundary between Canada and the United States;

(h)"Great Lakes System" means all of the streams river, lakes and other bodies of water that are within the drainage basin on the St. Lawrence River at or upstream from the point at which this river becomes the international boundary between Canada and the United States;

(i)"Harmful quantity" means any quantity of a substance that if discharged into receiving water would be inconsistent with the achievement of the General and Specific Objectives;

(j)"Hazardous polluting substance" means any element or compound identified by the Parties which, if discharged in any quantity into or upon receiving waters or adjoining shorelines, would present an imminent and substantial danger to public health or welfare; for this purpose, "public health or welfare" encompasses all factors affecting the health and welfare of humans including but not limited to human health, and conservation and protection of flora and fauna, public and private property, shorelines and beaches;

(k)"International Joint Commission" or "Commission" means the International Joint Commission established by the Boundary Waters Treaty;

(l)"Monitoring" means a scientifically designed system of continuing standardized measurements and observations and the evaluation thereof;

(m)"Objectives" means the General Objectives adopted pursuant to Article III and the Specific Objectives adopted pursuant to Article IV of this Agreement;

(n)"Parties" means the Government of Canada and the Government of the United States of America;

(o)"Phosphorus" means the element phosphorus present as a constituent of various organic and inorganic complexes and compounds;

(p)"Research" means development, interpretation and demonstration of advanced scientific knowledge for the resolution of issues but does not include monitoring and surveillance of water or air quality;

(q)"Science Advisory Board" means the Great Lakes Science Advisory Board of the International Joint Commission established pursuant to Article VIII of this Agreement;

(r)"Specific Objectives" means the concentration or quantity of a substance or level of effect that the Parties agree, after investigation, to recognize as a maximum or minimum desired limit for a defined body of water or portion thereof, taking into account the beneficial uses or level of environmental quality which the Parties desire to secure and protect;

(s)"State and Provincial Governments" means the Governments of the States of Illinois, Indiana, Michigan, Minnesota, New York, Ohio, Wisconsin, and the Commonwealth of Pennsylvania, and the Government of the Province of Ontario;

(t)"Surveillance" means specific observations and measurements relative to control or management;

(u)"Terms of Reference" means the Terms of Reference for the Joint Institutions and the Great Lakes Regional Office established pursuant to this Agreement, which are attached to and form an integral part of this Agreement;

(v)"Toxic substance" means a substance which can cause death, disease, behavioural abnormalities, cancer, genetic mutations, physiological or reproductive malfunctions or physical deformities in any organism or its offspring, or which can become poisonous after concentration in the food chain or in combination with other substances;

(w)"Tributary waters of the Great Lakes System" or "tributary waters" means all the waters within the Great Lakes System that are not boundary waters;

(x)"Water Quality Board" means the Great Lakes Water Quality Board of the International Joint Commission established pursuant to Article VIII of this Agreement.

ARTICLE II - PURPOSE

The purpose of the Parties is to restore and maintain the chemical, physical, and biological integrity of the waters of the Great Lakes Basin Ecosystem. In order to achieve this purpose, the Parties agree to make a maximum effort to develop programs, practices and technology necessary for a better understanding of the Great Lakes Basin Ecosystem and to eliminate or reduce to the maximum extent practicable the discharge of pollutants into the Great Lakes System.

Consistent with the provisions of this Agreement, it is the policy of the Parties that:

- (a)The discharge of toxic substances in toxic amounts be prohibited and the discharge of any or all persistent toxic substances be virtually eliminated;
- (b)Financial assistance to construct publicly owned waste treatment works be provided by a combination of local, state, provincial, and federal participation; and
- (c)Coordinated planning processes and best management practices be developed and implemented by the respective jurisdictions to ensure adequate control of all sources of pollutants.

ARTICLE III - GENERAL OBJECTIVES

The Parties adopt the following General Objectives for the Great Lakes System. These waters should be:

- (a)Free from substances that directly or indirectly enter the waters as a result of human activity and that will settle to form putrescent or otherwise objectionable sludge deposits, or that will adversely affect aquatic life or waterfowl;
- (b)Free from floating materials such as debris, oil, scum, and other immiscible substances resulting from human activities in amounts that are unsightly or deleterious;
- (c)Free from materials and heat directly or indirectly entering the water as a result of human activity that alone, or in combination with other materials, will produce colour, odour, taste, or other conditions in such a degree as to interfere with beneficial uses;
- (d)Free from materials and heat directly or indirectly entering the water as a result of human activity that alone, or in combination with other materials, will produce conditions that are toxic or harmful to human, animal, or aquatic life; and
- (e)Free from nutrients directly or indirectly entering the waters as a

result of human activity in amounts that create growths of aquatic life that interfere with beneficial uses.

ARTICLE IV - SPECIFIC OBJECTIVES

1. The Parties adopt the Specific Objectives for the boundary waters of the Great Lakes System as set forth in Annex 1, subject to the following:

(a) The Specific Objectives adopted pursuant to this Article represent the minimum levels of water quality desired in the boundary waters of the Great Lakes System and are not intended to preclude the establishment of more stringent requirements. (b) The determination of the achievement of Specific Objectives shall be based on statistically valid sampling data. (c) Notwithstanding the adoption of Specific Objectives, all reasonable and practicable measures shall be taken to maintain or improve the existing water quality in those areas of the boundary waters of the Great Lakes System where such water quality is better than that prescribed by the Specific Objectives, and in those areas having outstanding natural resource value. (d) The responsible regulatory agencies shall not consider flow augmentation as a substitute for adequate treatment to meet the Specific Objectives. (e) The Parties recognize that in certain areas of inshore waters natural phenomena exist which, despite the best efforts of the Parties, will prevent the achievement of some of the Specific Objectives. As early as possible, these areas should be identified explicitly by the appropriate jurisdictions and reported to the International Joint Commission. (f) The Parties recognize that there are areas in the boundary waters of the Great Lakes System where, due to human activity, one or more of the General or Specific Objectives of the Agreement are not being met. Pending virtual elimination of the persistent toxic substances in the Great Lakes System, the Parties, in cooperation with the State and Provincial Governments and the Commission, shall identify and work toward the elimination of:

(i) Areas of Concern pursuant to Annex 2; (ii) Critical Pollutants pursuant to Annex 2; and (iii) Point Source Impact Zones pursuant to Annex 2.2. The Specific Objectives for the boundary waters of the Great Lakes System or for particular portions thereof shall be kept under review by the Parties and the International Joint Commission, which shall make appropriate recommendations. 3. The Parties

shall consult on:

(a) The establishment of Specific Objectives to protect beneficial uses from the combined effects of pollutants; and (b) The control of pollutant loading rates for each lake basin to protect the integrity of the ecosystem over the long term.

ARTICLE V - STANDARDS, OTHER REGULATORY REQUIREMENTS, AND RESEARCH

1. Water quality standards and other regulatory requirements of the Parties shall be consistent with the achievement of the General and Specific Objectives. The Parties shall use their best efforts to ensure that water quality standards and other regulatory requirements of the State and Provincial Government shall similarly be consistent with the achievement of these Objectives. Flow augmentation shall not be considered as a substitute for adequate treatment to meet water quality standards or other regulatory requirements. 2. The Parties shall use their best efforts to ensure that: (a) The principal research funding agencies in both countries orient the research programs of their organizations in response to research priorities identified by the Science Advisory Board and recommended by the Commission; (b) Mechanisms be developed for appropriate cost-effective international cooperation; and (c) Research priorities are undertaken in accordance with Annex 17.

ARTICLE VI - PROGRAMS AND OTHER MEASURES

1. The Parties, in cooperation with State and Provincial Governments, shall continue to develop and implement programs and other measures to fulfil the purpose of this Agreement and to meet the General and Specific Objectives. Where present treatment is inadequate to meet the General and Specific Objectives, additional treatment shall be required. The programs and measures shall include the following:

(a) Pollution from Municipal Sources. Programs for the abatement, control and prevention of municipal discharges and urban drainage into the Great Lakes System. These programs shall be completed and in operation as soon as practicable, and in the case of municipal sewage treatment facilities no later than December 31, 1982. These programs shall include:

(i) Construction and operation of waste treatment facilities in all municipalities having sewer systems to provide levels of treatment consistent with the achievement of phosphorus requirements and the General and Specific Objectives, taking into account the effects of waste from other sources; (ii) Provision of financial resources to ensure prompt construction of needed facilities; (iii) Establishment of requirements for construction and operating standards for facilities; (iv) Establishment of pre-treatment requirements for all industrial plants discharging waste into publicly owned treatment works where such industrial wastes are not amenable to adequate treatment or removal using conventional municipal treatment processes; (v) Development and implementation of practical programs for reducing pollution from storm, sanitary, and combined sewer discharges; and (vi) Establishment of effective enforcement programs to ensure that the above pollution abatement requirements are fully met; (b) Pollution from Industrial Sources.

Programs for the abatement, control and prevention of pollution from industrial sources entering the Great Lakes System. These programs shall be completed and in operation as soon as practicable and in any case no later than December 31, 1983, and shall include:

(i) Establishment of water treatment or control requirements expressed as effluent limitations (concentrations and/or loading limits for specific pollutants where possible) for all industrial plants, including power generating facilities, to provide levels of treatment or reduction or elimination of inputs of substances and effects consistent with the achievement of the General and Specific Objectives and other control requirements, taking into account the effects of waste from other sources; (ii) Requirements for the substantial elimination of discharges into the Great Lakes System of persistent toxic substances; (iii) Requirements for control of thermal discharges; (iv) Measures to control the discharges of radioactive materials into the Great Lakes System; (v) Requirements to minimize adverse environmental impacts of water intakes; (vi) Development and implementation of programs to meet industrial pre-treatment requirements as specified under sub-paragraph (a) (iv) above; and (vii) Establishment of effective enforcement programs to ensure the above pollution abatement requirements are fully met; (c) Inventory of Pollution Abatement Requirements. Preparation of an inventory of pollution abatement requirements for all municipal and industrial facilities discharging into the Great Lakes System in order to gauge progress toward the earliest practicable completion and operation of the

programs listed in sub-paragraphs (a) and (b) above. This inventory, prepared and revised annually, shall include compliance schedules and status of compliance with monitoring and effluent restrictions, and shall be made available to the International Joint Commission and to the public. In the initial preparation of this inventory, priority shall be given to the problem areas previously identified by the Water Quality Board;(d)Eutrophication. Programs and measures for the reduction and control of inputs of phosphorus and other nutrients, in accordance with the provisions of Annex 3(e)Pollution from Agriculture, Forestry, and Other Land Use Activities. Measures for the abatement and control of pollution from agriculture, forestry and other land use activities including:

(i)Measures for the control of pest control products used in the Great Lakes Basin to ensure that pest control products likely to have long term deleterious effects on the quality of water or its biota be used only as authorized by the responsible regulatory agencies; that inventories of pest control products used in the Great Lakes Basin be established and maintained by appropriate agencies; and that research and educational programs be strengthened to facilitate integration of cultural, biological and chemical pest control techniques;(ii)Measures for the abatement and control of pollution from animal husbandry operations, including encouragement to appropriate agencies to adopt policies and regulations regarding utilization of animal wastes, and site selection and disposal of liquid and solid wastes, and to strengthen educational and technical assistance programs to enable farmers to establish waste utilization, handling and disposal systems;(iii)Measures governing the hauling and disposal of liquid and solid wastes, including encouragement to appropriate regulatory agencies to ensure proper location, design and regulation governing land disposal, and to ensure sufficient, adequately trained technical and administrative capability to review plans and to supervise and monitor systems for application of wastes on land;(iv)Measures to review and supervise road salting practices and salt storage to ensure optimum use of salt and all-weather protection of salt stores in consideration of long-term environmental impact;(v)Measures to control soil losses from urban and suburban as well as rural areas;(vi)Measures to encourage and facilitate improvements in land use planning and management programs to take account of impacts on Great Lakes water quality;(vii)Other advisory programs and measures to abate and control inputs of nutrients, toxic substances and sediments from agricultural, forestry and other land use activities;(viii)Consideration of future recommendations from the International Joint Commission based on the Pollution from Land Use Activities Reference; and(ix)Conduct further non-point source programs in accordance with Annex 13;(f)Pollution from Shipping Activities. Measures for the abatement and control of pollution from shipping sources, including:

(i)Programs and compatible regulations to prevent discharges of harmful quantities of oil and hazardous polluting substances, in accordance with Annex 4;(ii)Compatible regulations for the control of discharges of vessel wastes, in accordance with Annex 5;(iii)Such compatible regulations to abate and control pollution from shipping sources as may be deemed desirable in the light of continuing reviews and studies to be undertaken in accordance with Annex 6;(iv)Programs and any necessary compatible regulations in accordance with Annexes 4 and 5, for the safe and efficient handling of shipboard generated wastes, including oil, hazardous polluting substances, garbage, waste water and sewage, and for their subsequent disposal, including the type and quantity of reception facilities and, if applicable, treatment standards; and(v)Establishment by the Canadian Coast Guard and the United States Coast Guard of a coordinated system for aerial and surface surveillance for the purpose of enforcement of regulations and the early identification, abatement and clean-up of spills of oil, hazardous polluting substances, or other

pollution;(g)Pollution from Dredging Activities. Measures for the abatement and control of pollution from all dredging activities, including the development of criteria for the identification of polluted sediments and compatible programs for disposal of polluted dredged material, in accordance with Annex 7. Pending the development of compatible criteria and programs, dredging operations shall be conducted in a manner that will minimize adverse effects on the environment;(h)Pollution from Onshore and Offshore Facilities. Measures for the abatement and control of pollution from onshore and offshore facilities, including programs and compatible regulations for the prevention of discharges of harmful quantities of oil and hazardous polluting substances, in accordance with Annex 8;(i)Contingency Plan. Maintenance of a joint contingency plan for use in the event of a discharge or the imminent threat of a discharge of oil or hazardous polluting substances, in accordance with Annex 9;(j)Hazardous Polluting Substances. Implementation of Annex 10 concerning hazardous polluting substances. The Parties shall further consult from time to time for the purpose of revising the list of hazardous polluting substances and of identifying harmful quantities of these substances;(k)Persistent Toxic Substances. Measures for the control of inputs of persistent toxic substances including control programs for their production, use, distribution and disposal, in accordance with Annex 12;(l)Airborne Toxic Substances. Programs to identify pollutant sources and relative source contribution, including the more accurate definition of wet and dry deposition rates, for those substances which may have significant adverse effects on environmental quality including the indirect effects of impairment of tributary water quality through atmospheric deposition in drainage basins. In cases where significant contributions to Great Lakes pollution from atmospheric sources are identified, the Parties agree to consult on appropriate remedial programs. The Parties shall conduct such programs in accordance with Annex 15;(m)Surveillance and Monitoring. Implementation of a coordinated surveillance and monitoring program in the Great Lakes System, in accordance with Annex 11, to assess compliance with pollution control requirements and achievement of the Objectives, to provide information for measuring local and whole lake response to control measures, and to identify emerging problems.(n)Remedial Action Plans. Measures to ensure the development and implementation of Remedial Action Plans for Areas of Concern pursuant to Annex 2;(o)Lakewide Management Plans. Measures to ensure the development and implementation of Lakewide Management Plans to address Critical Pollutants pursuant to Annex 2.(p)Pollution from Contaminated Sediments. Measures for the abatement and control of pollution from all contaminated sediments, including the development of chemical and biological criteria for assessing the significance of the relative contamination arising from the sediments and compatible programs for remedial action for polluted sediments in accordance with Annex 14; and(q)Pollution from Contaminated Groundwater and Subsurface Sources. Programs for the assessment and control of contaminated groundwater and subsurface sources entering the boundary waters of the Great Lakes System pursuant to Annex 16.2.The Parties shall develop and implement such additional programs as they jointly decide are necessary and desirable to fulfil the purpose of this Agreement and to meet the General and Specific Objectives.The Parties shall develop and implement such additional programs as they jointly decide are necessary and desirable to fulfil the purpose of this Agreement and to meet the General and Specific Objectives.

ARTICLE VII - POWERS, RESPONSIBILITIES AND FUNCTIONS OF THE INTERNATIONAL JOINT COMMISSION

1. The International Joint Commission shall assist in the implementation of this Agreement. Accordingly, the Commission is hereby given, by a Reference pursuant to Article IX of the Boundary Waters Treaty, the following responsibilities:

(a) Collation, analysis and dissemination of data and information supplied by the Parties and State and Provincial Governments relating to the quality of the boundary waters of the Great Lakes System and to pollution that enters the boundary waters from tributary waters and other sources; (b) Collection, analysis and dissemination of data and information concerning the General and Specific Objectives and the operation and effectiveness of the programs and other measures established pursuant to this Agreement; (c) Tendering of advice and recommendations to the Parties and to the State and Provincial Governments on problems of and matters related to the quality of the boundary waters of the Great Lakes System including specific recommendations concerning the General and Specific Objectives, legislation, standards and other regulatory requirements, programs and other measures, and intergovernmental agreements relating to the quality of these waters; (d) Tendering of advice and recommendations to the Parties in connection with matters covered under the Annexes to this Agreement; (e) Provision of assistance in the coordination of the joint activities envisaged by this Agreement; (f) Provision of assistance in and advice on matters related to research in the Great Lakes Basin Ecosystem, including identification of objectives for research activities, tendering of advice and recommendations concerning research to the Parties and to the State and Provincial Governments, and dissemination of information concerning research to interested persons and agencies; (g) Investigations of such subjects related to the Great Lakes Basin Ecosystem as the Parties may from time to time refer to it.

2. In the discharge of its responsibilities under this Reference, the Commission may exercise all of the powers conferred upon it by the Boundary Waters Treaty and by any legislation passed pursuant thereto including the power to conduct public hearings and to compel the testimony of witnesses and the production of documents.

3. The Commission shall make a full report to the Parties and to the State and Provincial Governments no less frequently than biennially concerning progress toward the achievement of the General and Specific Objectives including, as appropriate, matters related to Annexes to this Agreement. This report shall include an assessment of the effectiveness of the programs and other measures undertaken pursuant to this Agreement, and advice and recommendations. In alternate years, the Commission may submit a summary report. The Commission may at any time make

special reports to the Parties, to the State and Provincial Governments and to the public concerning any problem of water quality in the Great Lakes System.4.The Commission may in its discretion publish any report, statement or other document prepared by it in the discharge of its functions under this Reference.5.The Commission shall have authority to verify independently the data and other information submitted by the Parties and by the State and Provincial Governments through such tests or other means as appear appropriate to it, consistent with the Boundary Waters Treaty and with applicable legislation.6.The Commission shall carry out its responsibilities under the Reference utilizing principally the services of the Water Quality Board and the Science Advisory Board established under Article VIII of this Agreement. The Commission shall also ensure liaison and coordination between the institutions established under this Agreement and other institutions which may address concerns relevant to the Great Lakes Basin Ecosystem, including both those within its purview, such as those Boards related to the Great Lakes levels and air pollution matters, and other international bodies as appropriate.

ARTICLE VIII - JOINT INSTITUTIONS AND REGIONAL OFFICE

1.To assist the International Joint Commission in the exercise of the powers and responsibilities assigned to it under this Agreement, there shall be two Boards:

(a)A Great Lakes Water Quality Board which shall be the principal advisor to the Commission. The Board shall be composed of an equal number of members from Canada and the United States, including representatives from the Parties and each of the State and Provincial Governments;

and(b)A Great Lakes Science Advisory Board shall provide advice on research to the Commission and to the Water Quality Board. The Board shall further provide advice on scientific matters referred to it by the Commission, or by the Water Quality Board in consultation with the Commission. The Science Advisory Board shall consist of managers of Great Lakes research programs and recognized experts on Great Lakes water quality problems and related fields.2.The members of the Water Quality Board and the Science Advisory Board shall be appointed by the Commission after consultation with the appropriate government or governments concerned. The functions of the Boards shall be as specified in the terms of Reference appended to this

Agreement.3.To provide administrative support and technical assistance to the two Boards, and to provide information service for the programs, including public hearings, undertaken by the International Joint Commission and by the Boards, there shall be a Great Lakes Regional Office of the International Joint Commission. Specific duties and organization of the Office shall be as specified in the Terms of Reference appended to this Agreement.4.The Commission shall submit an annual budget of anticipated expenses to be incurred in carrying out its responsibilities under this Agreement to the Parties for approval. Each Party shall seek funds to pay one-half of the annual budget so approved, but neither Party shall be under an obligation to pay a larger amount than the other toward this budget.

ARTICLE IX - SUBMISSION AND EXCHANGE OF INFORMATION

1.The International Joint Commission shall be given at its request any data or other information relating to water quality in the Great Lakes System in accordance with procedures established by the Commission.2.The Commission shall make available to the Parties and to the State and Provincial Governments upon request all data or other information furnished to it in accordance with the Article.3.Each Party shall make available to the other at its request any data or other information in its control relating to water quality in the Great Lakes System.4.Notwithstanding any other provision of this Agreement, the Commission shall not release without the consent of the owner any information identified as proprietary information under the law of the place where such information has been acquired.

ARTICLE X - CONSULTATION AND REVIEW

1. Following the receipt of each report submitted to the Parties by the International Joint Commission in accordance with paragraph 3 of Article VII of this Agreement, the Parties shall consult on the recommendations contained in such report and shall consider such action as may be appropriate, including:

(a) The modification of existing Objectives and the adoption of new Objectives; (b) The modification or improvement of programs and joint measures; and (c) The amendment of this Agreement or any Annex thereto. Additional consultations may be held at the request of either Party on any matter arising out of the implementation of this Agreement. 2. When a Party becomes aware of a special pollution problem that is of joint concern and requires an immediate response, it shall notify and consult the other Party forthwith about appropriate remedial action. 3. The Parties, in cooperation with State and Provincial Governments, shall meet twice a year to coordinate their respective work plans with regard to the implementation of this Agreement and to evaluate progress made. 4. The Parties shall conduct a comprehensive review of the operation and effectiveness of this Agreement following every third biennial report of the Commission required under Article VII of this Agreement.

ARTICLE XI - IMPLEMENTATION

1. The obligations undertaken in this Agreement shall be subject to the appropriation of funds in accordance with the constitutional procedures of the Parties. 2. The Parties commit themselves to seek:

(a) The appropriation of funds required to implement this Agreement, including the funds needed to develop and implement the programs and other measures provided for in Article VI of this Agreement, and the funds required by the International Joint Commission to carry out its responsibilities effectively; (b) The enactment of any additional legislation that may be necessary in order to implement the programs and other measures provided for in Article VI of this Agreement; and (c) The cooperation of the State and Provincial Governments in all matters relating to this Agreement.

ARTICLE XII - EXISTING RIGHTS AND OBLIGATIONS

Nothing in this Agreement shall be deemed to diminish the rights and obligations of the Parties as set forth in the Boundary Waters Treaty.

ARTICLE XIII - AMENDMENT

1. This Agreement, the Annexes, and the Terms of Reference may be amended by agreement of the Parties. The Annexes may also be amended as provided therein, subject to the requirement that such amendments shall be within the scope of this Agreement. All such amendments to the Annexes shall be confirmed by an exchange of notes or letters between the Parties through diplomatic channels which shall specify the effective date or dates of such amendments. 2. All amendments to this Agreement, the Annexes, and the Terms of Reference shall be communicated promptly to the International Joint Commission.

ARTICLE XIV - ENTRY INTO FORCE AND TERMINATION

This Agreement shall enter into force upon signature by the duly authorized representatives of the Parties, and shall remain in force for a period of five years and thereafter until terminated upon twelve months' notice given in writing by one of the Parties to the other.

ARTICLE XV - SUPERSESSION

This Agreement supersedes the Great Lakes Water Quality Agreement of April 15, 1972, and shall be referred to as the "Great Lakes Water Quality Agreement of 1978".

IN WITNESS WHEREOF the undersigned representatives, duly authorized by their respective Governments, have signed this Agreement.

DONE in duplicate at Ottawa in the English and French languages, both versions being equally authentic, this 22nd day of November 1978.

EN FOI DE QUOI, les repr sentants soussign es, d  ment autoris es par leur Gouvernement respectif, ont sign  le pr sent Accord.

FAIT en double exemplaire   Ottawa en fran ais et en anglais, chaque version faisant  galement foi, ce 22e jour de novembre 1978.

ANNEX 1 - SPECIFIC OBJECTIVES

These Objectives are based on available information on cause/effect relationships between pollutants and receptors to protect the recognized most sensitive use in all waters. These Objectives may be amended, or new Objectives may be added, by mutual consent of the Parties.

I. CHEMICAL

A. Persistent Toxic Substances

1. Organic

(a) Pesticides

Aldrin/Dieldrin The sum of the concentration of aldrin and dieldrin in water should not exceed 0.001 micrograms per litre. The sum of concentrations of aldrin and dieldrin in the edible portion of fish should not exceed 0.3 micrograms per gram (wet weight basis) for the protection of human consumers of fish.

Chlordane The concentration of chlordane in water should not exceed 0.06 micrograms per litre for the protection of aquatic life.

DDT and Metabolites The sum of the concentrations of DDT and its metabolites in water should not exceed 0.003 micrograms per litre. The sum of the concentrations of DDT and its metabolites in whole fish should not exceed 1.0 microgram per gram (wet weight basis) for the protection of fish-consuming aquatic birds.

Endrin The concentration of endrin in water should not exceed 0.002 micrograms per litre. The concentration of endrin in the edible portion of fish should not exceed 0.3 micrograms per gram (wet weight basis) for the protection of human consumers of fish.

Heptachlor/Heptachlor Epoxide The sum of the concentrations of heptachlor and heptachlor epoxide in water should not exceed 0.001 micrograms per litre. The sum of concentrations of heptachlor and heptachlor epoxide in edible portions of fish should not exceed 0.3 micrograms per gram (wet weight basis) for the protection of human consumers of fish.

Lindane The concentration of lindane in water should not exceed 0.01 micrograms per litre for the protection of aquatic life. The concentration of lindane in edible portions of fish should not exceed 0.3 micrograms per gram (wet weight basis) for the protection of human consumers of fish.

Methoxychlor The concentration of methoxychlor in water should not exceed 0.04 micrograms per litre for the protection of aquatic life.

Mirex For the protection of aquatic organisms and fish-consuming birds and animals, mirex and its degradation products should be substantially absent from water and aquatic organisms. Substantially absent here means less than detection levels as determined by the best scientific methodology available.

Toxaphene The concentration of toxaphene in water should not exceed 0.008 micrograms per litre for the protection of aquatic life.

(b) Other Compounds

Phthalic Acid Esters The concentration of dibutyl phthalate and di (2-ethylhexyl) phthalate in water should not exceed 4.0 micrograms per litre and 0.6 micrograms per litre, respectively, for the protection of aquatic life. Other phthalic acid esters should not exceed 0.2 micrograms per litre in

waters for the protection of aquatic life. Polychlorinated Biphenyls (PCBs) The concentration of total polychlorinated biphenyls in fish tissues (whole fish, calculated on a wet weight basis), should not exceed 0.1 micrograms per gram for the protection of birds and animals which consume fish. Unspecific Organic Compounds For other organic contaminants, for which Specific Objectives have not been defined, but which can be demonstrated to be persistent and are likely to be toxic, the concentrations of such compounds in water or aquatic organisms should be substantially absent, i.e., less than detection levels as determined by the best scientific methodology available. 2. Inorganic

(a) Metals

Arsenic The concentrations of total arsenic in an unfiltered water sample should not exceed 50 micrograms per litre to protect raw waters for public water supplies. Cadmium The concentration of total cadmium in an unfiltered water sample should not exceed 0.2 micrograms per litre to protect aquatic life. Chromium The concentration of total chromium in an unfiltered water sample should not exceed 50 micrograms per litre to protect raw waters of public water supplies. Copper The concentration of total copper in an unfiltered water sample should not exceed 5 micrograms per litre to protect aquatic life. Iron The concentration of total iron in an unfiltered water sample should not exceed 300 micrograms per litre to protect aquatic life. Lead The concentration of total lead in an unfiltered water sample should not exceed 10 micrograms per litre in Lake Superior, 20 micrograms per litre in Lake Huron and 25 micrograms per litre in all remaining Great Lakes to protect aquatic life. Mercury The concentration of total mercury in a filtered water sample should not exceed 0.2 micrograms per litre nor should the concentration of total mercury in whole fish exceed 0.5 micrograms per gram (wet weight basis) to protect aquatic life and fish-consuming birds. Nickel The concentration of total nickel in an unfiltered water sample should not exceed 25 micrograms per litre to protect aquatic life. Selenium The concentration of total selenium in an unfiltered water sample should not exceed 10 micrograms per litre to protect the raw water for public water supplies. Zinc The concentration of total zinc in an unfiltered water sample should not exceed 30 micrograms per litre to protect aquatic life. (b) Other Inorganic Substances

Fluoride The concentration of total fluoride in an unfiltered water sample should not exceed 1200 micrograms per litre to protect raw water for public water supplies. Total Dissolved Solids In Lake Erie, Lake Ontario and the International Section of the St. Lawrence River, the level of total dissolved solids should not exceed 200 milligrams per litre. In the St. Clair River, Lake St. Clair, the Detroit River and the Niagara River, the level should be consistent with maintaining the levels of total dissolved solids in Lake Erie and Lake Ontario not to exceed 200 milligrams per litre. In the remaining boundary waters, pending further study, the level of total dissolved solids should not exceed present levels. B. Non-Persistent Toxic Substances

1. Organic Substances

(a) Pesticides

Diazinon The concentration of diazinon in an unfiltered water sample should not exceed 0.08 micrograms per litre for the protection of aquatic life. Guthion The concentration of guthion in an unfiltered water sample should not exceed 0.005 micrograms per litre for the protection of aquatic life. Parathion The concentration of parathion in an unfiltered water sample should not exceed 0.008 micrograms per litre for the protection of aquatic life. Other Pesticides The concentration of unspecified, non-persistent pesticides should not exceed 0.05 of the median lethal concentration on a 96-hour test for any sensitive local species. (b) Other substances

Unspecified Non-Persistent Toxic Substances and Complex Effluents Unspecified non-persistent

toxic substances and complex effluents of municipal, industrial or other origin should not be present in concentrations which exceed 0.05 of the median lethal concentration in a 96-hour test for any sensitive local species to protect aquatic life. Oil and Petrochemicals Oil and petrochemicals should not be present in concentrations that:

(i) can be detected as visible film, sheen or discoloration on the surface; (ii) can be detected by odour; (iii) can cause tainting of edible aquatic organisms; and (iv) can form deposits on shorelines and bottom sediments that are detectable by sight or odour, or are deleterious to resident aquatic organisms.

2. Inorganic Substances

Ammonia The concentration of un-ionized ammonia (NH_3) should not exceed 20 micrograms per litre for the protection of aquatic life. Concentrations of total ammonia should not exceed 500 micrograms per litre for the protection of public water supplies.

Hydrogen Sulfide The concentration of undissociated hydrogen sulfide should not exceed 2.0 micrograms per litre to protect aquatic life.

C. Other Substances

1. Dissolved oxygen In the connecting channels and in the upper waters of the Lakes, the dissolved oxygen level should not be less than 6.0 milligrams per litre at any time; in hypolimnetic waters, it should be not less than necessary for the support of fishlife, particularly cold water species.

2. pH Values of pH should not be outside the range of 6.5 to 9.0, nor should discharge change the pH at the boundary of a limited use zone more than 0.5 units from that of the ambient waters.

3. Nutrients Phosphorus The concentration should be limited to the extent necessary to prevent nuisance growths of algae, weeds and slimes that are or may become injurious to any beneficial water use. (Specific phosphorus control requirements are set out in Annex 3.)

4. Tainting Substances

(a) Raw public water supply sources should be essentially free from objectionable taste and odour for aesthetic reasons. (b) Levels of phenolic compounds should not exceed 1.0 microgram per litre in public water supplies to protect against taste and odour in domestic water. (c) Substances entering the water as the result of human activity that cause tainting of edible aquatic organisms should not be present in concentrations which will lower the acceptability of these organisms as determined by organoleptic tests.

II. PHYSICAL

A. Asbestos Asbestos should be kept at the lowest practical level and in any event should be controlled to the extent necessary to prevent harmful effects on human health. **B. Temperature** There should be no change in temperature that would adversely affect any local or general use of the

waters. C. Settleable and Suspended Solids, and Light Transmission For the protection of aquatic life, waters should be free from substances attributable to municipal, industrial or other discharges resulting from human activity that will settle to form putrescent or otherwise objectionable sludge deposits or that will alter the value of Secchi disc depth by more than 10 per cent.

III. MICROBIOLOGICAL

Waters used for body contact recreation activities should be substantially free from bacteria, fungi, or viruses that may produce enteric disorders or eye, ear, nose, throat and skin infections or other human diseases and infections.

IV. RADIOLOGICAL

The level of radioactivity in waters outside of any defined source control area should not result in a TED50 (total equivalent dose integrated over 50 years as calculated in accordance with the methodology established by the International Commission on Radiological Protection) greater than 1 millirem to the whole body from a daily ingestion of 2.2 litres of lake water for one year. For dose commitments between 1 and 5 millirem at the periphery of the source control area, source

investigation and corrective action are recommended if releases are not as low as reasonably achievable. For dose commitments greater than 5 millirem, the responsible regulatory authorities shall determine appropriate corrective action.

SPECIFIC OBJECTIVES - SUPPLEMENT TO ANNEX 1

1. General Principles

(a) Interim Objectives for Persistent Toxic Substances Consistent with the policy stated in paragraph (a) of Article II and Paragraph 2 of Annex 12 that the discharge of any or all persistent toxic substances be virtually eliminated, the Specific Objectives set out in Annex 1 for such substances are adopted as interim objectives. (b) Detection Levels As used in this Annex, "absent" means that the substances are not detectable when analyzed using the best available technology, which may include biological indicators. Detection levels will be subject to change as technology improves and new levels are adopted.

2. Specific Objectives Review Process

(a) The Parties, in consultation with State and Provincial Governments, shall consult on or before July 1, 1988, and at least once every two years thereafter for the purpose of considering the adoption of proposals by the Parties, State and Provincial Governments or recommendations of the Commission to:

(i) establish or modify Specific Objectives under Annex 1; and (ii) establish action levels under Annex 12. The Parties, in cooperation with State and Provincial Governments, shall ensure that the public is consulted in the development and adoption of the Specific Objectives. (b) In proposing a substance for a new Specific Objective, the Parties, State and Provincial Governments or the Commission shall be guided by, but not limited to, the lists prepared by the Parties under paragraph (c), below, identifying substances that are present or potentially present within the water, sediment or aquatic biota of the Great Lakes System and are believed, singly or in synergistic or additive combination with another substance, to have acute or chronic toxic effects on aquatic, animal or human life. (c) The Parties, on or before December 31, 1988, shall compile and maintain three lists of substances as follows:

(i) List No. 1 shall consist of all substances (1) believed to be present within the water, sediment

or aquatic biota of the Great Lakes System and (2) believed, singly or in synergistic or additive combination with another substance, to have acute or chronic toxic effects on aquatic, animal or human life. (ii) List No. 2 shall consist of all substances (1) believed to be present within the water, sediment or aquatic biota of the Great Lakes System and (2) believed, singly, or in synergistic or additive combination with another substance to have the potential to cause acute or chronic toxic effects on aquatic, animal or human life. (iii) List No. 3 shall consist of all substances (1) believed to have the potential of being discharged into the Great Lakes System and (2) believed, singly or in synergistic or additive combination with another substance, to have acute or chronic toxic effects on aquatic, animal or human life. In compiling such lists, the Parties shall employ all data available, including that resulting from activities undertaken pursuant to Annex

12. (d) Determinations regarding whether a substance, singly or in synergistic or additive combinations with another substance, has actual or potential acute or chronic effects or whether a substance has the potential of being discharged into the Great Lakes System according to paragraph (c) above, shall be made using standard methods agreed to by the Parties in consultation with State and Provincial Governments by April 1988. 3. Lake Ecosystem Objectives. Consistent with the purpose of this Agreement to maintain the chemical, physical and biological integrity of the waters of the Great Lakes Basin Ecosystem, the Parties, in consultation with State and Provincial Governments, agree to develop the following ecosystem objectives for the boundary waters of the Great Lakes System, or portions thereof, and for Lake Michigan:

(a) Lake Superior The Lake should be maintained as a balanced and stable oligotrophic ecosystem with lake trout as the top aquatic predator of a cold-water community and the *Pontoporeia hoyi* as a key organism in a food chain; and (b) Other Great Lakes Ecosystem Objectives shall be developed as the state of knowledge permits for the rest of the boundary of the Great Lakes System, or portions thereof, and for Lake Michigan.

ANNEX 2 - REMEDIAL ACTION PLANS AND LAKEWIDE MANAGEMENT PLANS

1. Definitions. As used in this Annex:

(a) "Area of Concern" means a geographic area that fails to meet the General or Specific

Objectives of the Agreement where such failure has caused or is likely to cause impairment of beneficial use or of the area's ability to support aquatic life.(b)"Critical Pollutants" means substances that persist at levels that, singly or in synergistic or additive combination, are causing, or are likely to cause, impairment of beneficial uses despite past application of regulatory controls due to their:

(i)presence in open lake waters;(ii)ability to cause or contribute to a failure to meet Agreement objectives through their recognized threat to human health and aquatic life; or(iii)ability to bioaccumulate.(c)"Impairment of beneficial use(s)" means a change in the chemical, physical or biological integrity of the Great Lakes System sufficient to cause any of the following:

(i)restrictions on fish and wildlife consumption;(ii)tainting of fish and wildlife flavour;(iii)degradation of fish wildlife populations;(iv)fish tumors or other deformities;(v)bird or animal deformities or reproduction problems;(vi)degradation of benthos;(vii)restrictions on dredging activities;(viii)eutrophication or undesirable algae;(ix)restrictions on drinking water consumption, or taste and odour problems(x)beach closings;(xi)degradation of aesthetics;(xii)added costs to agriculture or industry;(xiii)degradation of phytoplankton and zooplankton populations; and(xiv)loss of fish and wildlife habitat.(d)"Point Source Impact Zone" is defined as an area of water contiguous to a point source where the water quality does not comply with the General and Specific Objectives of this Agreement.2.General Principles

(a)Remedial Action Plans and Lakewide Management Plans shall embody a systematic and comprehensive ecosystem approach to restoring and protecting beneficial uses in Areas of Concern or in open lake waters.(b)Such Plans shall provide a continuing historical record of the assessment of Areas of Concern or Critical Pollutants, proposed remedial actions and their method of implementation, as well as changes in environmental conditions that result from such actions, including significant milestones in restoring beneficial uses to Areas of Concern or open lake waters. They are to serve as an important step toward virtual elimination of persistent toxic substances and toward restoring and maintaining the chemical, physical and biological integrity of the Great Lakes Basin Ecosystem.(c)The Parties, State and Provincial Governments, and the Commission have identified Areas of Concern and the development of the of Remedial Action Plans for them has begun. Furthermore, the Parties and State and Provincial Governments have begun developing lakewide strategies for Lakes Ontario and Michigan. By incorporating an Annex for Remedial Action Plans and Lakewide Management Plans in this Agreement, the Parties intend to endorse and build upon these existing efforts.(d)Point source impact zones exist in the vicinity of some point source discharges. Pending the achievement of the virtual elimination of persistent toxic substances, the size of such zones shall be reduced to the maximum extent possible by the best available technology so as to limit the effects of toxic substances in the vicinity of these discharges. These zones shall not be acutely toxic to aquatic species, nor shall their recognition be considered a substitute for adequate treatment or control of discharges at their sources.(e)The Parties, in cooperation with State and Provincial Governments, shall ensure that the public is consulted in all actions undertaken pursuant to this Annex.3.Designation of Areas of Concern. The Parties, in cooperation with State and Provincial Governments and the Commission, shall designate geographic Areas of Concern. The Commission, in its evaluation role, shall review progress in addressing Areas of Concern, and recommend additional Areas of Concern for designation by each Party.4.Remedial Action Plans for Areas of Concern

(a)The Parties shall cooperate with State and Provincial Governments to ensure that Remedial Action Plans are developed and implemented for Areas of Concern. Each plan shall include:

(i)a definition and detailed description of the environmental problem in the Areas of Concern,

including a definition of the beneficial uses that are impaired, the degree of impairment and the geographic extent of such impairment;(ii)a definition of the causes of the use impairment, including a description of all known sources of pollutants involved and an evaluation of other possible sources;(iii)an evaluation of remedial measures in place;(iv)an evaluation of alternative additional measures to restore beneficial uses;(v)a selection of additional remedial measures to restore beneficial uses and a schedule for their implementation;(vi)an identification of the persons or agencies responsible for implementation of remedial measures;(vii)a process for evaluating remedial measure implementation and effectiveness; and(viii)a description of surveillance and monitoring processes to track the effectiveness of remedial measures and the eventual confirmation of the restoration of uses.(b)The Parties, in cooperation with State and Provincial Governments, shall ensure that affected State and Provincial Governments not now covered by this Agreement will be involved in the development of such plans and consulted on their implementation.(c)The Parties shall cooperate with State and Provincial Governments to classify Areas of Concern by their stage of restoration progressing from the definition of the problems and causes, through the selection of remedial measures, to the implementation of remedial programs, the monitoring of recovery, and, when identified beneficial uses are no longer impaired and the area restored, the removal of its designation as an Area of Concern.(d)The Remedial Action Plans shall be submitted to the Commission for review and comment at three stages:

(i)when a definition of the problem has been completed under sub-paragraphs 4 (a) (i) and (ii);(ii)when remedial and regulatory measures are selected under sub-paragraphs 4 (a)(iii), (iv),(v) and (vi); and(iii)when monitoring indicates that identified beneficial uses have been restored under sub-paragraphs 4(a) (vii) and (viii).5.Designation of Critical Pollutants for the Development of Lakewide Management Plans. The Parties, in cooperation with State and Provincial Governments and the Commission, shall designate Critical Pollutants for the boundary waters of the Great Lakes System or for a portion thereof. The Commission, in its evaluative role, shall review progress in addressing Critical Pollutants and recommend additional Critical Pollutants for designation by the Parties. Substances on List No. 1 under Annex 1 Supplement shall be considered for designation as Critical Pollutants.6.Lakewide Management Plans for Critical Pollutants

(a)The Parties, in consultation with State and Provincial Governments, shall develop and implement Lakewide Management Plans for open lake waters, except for Lake Michigan where the Government of the United States of America shall have that responsibility. Such Plans shall be designed to reduce loadings of Critical Pollutants in order to restore beneficial uses, Lakewide Management Plans shall not allow increases in pollutant loadings in areas where Specific Objectives are not exceeded.

Such Plans shall include:

(i)a definition of the threat to human health or aquatic life posed by Critical Pollutants, singly or in synergistic or additive combinations with another substance, including their contribution to the impairment of beneficial uses;(ii)an evaluation of information available on concentration, sources, and pathways of the Critical Pollutants in the Great Lakes System, including all information on loadings of the Critical Pollutants from all sources, and an estimation of total loadings of the Critical Pollutants by modelling or other identified methods;(iii)steps to be taken pursuant to Article VI of this Agreement to develop the information necessary to determine the schedule of load reduction of Critical Pollutants that would result in meeting Agreement Objectives, including steps to develop the necessary standard approached and agreed procedures;(iv)a determination of

load reduction of Critical Pollutants necessary to meet Agreement Objectives;(v)an evaluation of remedial measures presently in place, and alternative additional measures that could be applied to decrease loadings of Critical Pollutants;(vi)identification of the additional remedial measures that are need to achieve the reduction of loadings and to eliminate the contribution to impairment of beneficial uses from Critical Pollutants, including an implementation schedule;(vii)identification of the persons or agencies responsible for implementation of the remedial measures in question;(viii)a process for evaluating remedial measure implementation and effectiveness;(ix)a description of surveillance and monitoring to track the effectiveness of the remedial measures and the eventual elimination of the contribution to impairments of beneficial uses from the Critical Pollutants;(x)a process for recognizing the absence of a Critical Pollutant in open lake waters.

(b)The Parties shall classify efforts to reduce Critical Pollutants by their stages of elimination progressing from the definition of the problem, through the selection of remedial measures, to the implementation of remedial programs, the monitoring of recovery, and the removal of designation as a Critical Pollutant when it is no longer likely to cause, singly or in synergistic or additive combination with another substance, impairment of identified beneficial uses.(c)Lakewide Management Plans shall be submitted to the Commission for review and comment at four stages; (i)When a definition of the problem has been completed under sub-paragraphs 6 (a)(i), (ii) and (iii);(ii)When the schedule of load reductions is determined under paragraph 6(a) (i), (ii) and (iii);(iii)When remedial measures are selected under sub-paragraph 6 (a)(v), (vi) and (vii); and(iv)When monitoring indicates that the contribution of the Critical Pollutants to impairment of identified beneficial uses has been eliminated under sub-paragraphs 6(a)(viii) and (ix)7.Reporting Progress

(a)Point Source Impact Zones that are associated with direct significant discharges of industrial and municipal wastes shall be identified delineated and reported to the Commission beginning September 30, 1989. They shall be reviewed biennially and their limits revised to achieve the maximum possible reduction in size and effect in accordance with improvements in waste treatment technology and consistent with the policy of virtual elimination of persistent toxic substances.(b)The Parties shall report, by December 31, 1988, and biennially thereafter, to the Commission on the progress in developing and implementing the Remedial Action Plans and Lakewide Management Plans and in restoring beneficial uses. Information from these reports shall be included in the Commission's biennial report under paragraph 3 of Article VII.

ANNEX 3 - CONTROL OF PHOSPHORUS

1. The purpose of the following programs is to minimize eutrophication problems and to prevent degradation with regard to phosphorus in the boundary waters of the Great Lakes System. The Goals of phosphorus control are:

(a) Restoration of year-round aerobic conditions in the bottom waters of the Central Basin of Lake Erie; (b) Substantial reduction in the present levels of algal biomass to a level below that of a nuisance condition in Lake Erie; (c) Reduction in present levels of algal biomass to below that of a nuisance condition in Lake Ontario unleading the International Section of the St. Lawrence River; (d) Maintenance of the oligotrophic state and relative algal biomass of Lakes Superior and Huron; (e) Substantial elimination of algal nuisance growths in Lake Michigan to restore it to oligotrophic state; and (f) The elimination of algal nuisance in bays and in other areas wherever they occur.

2. The following programs shall be developed and implemented to reduce input of phosphorus to the Great Lakes:

(a) Construction and operation of municipal waste treatment facilities in all plants discharging more than one million gallons per day to achieve, where necessary to meet the loading allocation be developed pursuant to paragraph 3 below, or to meet local conditions, whichever are more stringent, effluent concentration of 1.0 milligram per litre total phosphorus maximum for plants in the basins of Lakes Superior, Michigan, and Huron, and of 0.5 milligram per litre total phosphorus maximum for plants in the basins of Lakes Ontario and Erie. (b) Regulation of phosphorus introduction from industrial discharges to the maximum practicable extent. (c) Reduction to the maximum extent practicable of phosphorus introduced from diffuse sources into Lakes Superior, Michigan, and Huron; and the reduction by 30 per cent of phosphorus introduced from diffuse sources into Lakes Ontario and Erie, where necessary to meet the loading allocations to be developed pursuant to paragraph 3 below, or to meet local conditions, whichever is more stringent. (d) Reduction of phosphorus in household detergents to 0.5 per cent by weight where necessary to meet the loading allocation to be developed pursuant to paragraph 3 below, or to meet local conditions, whichever are more stringent. (e) Maintenance of a viable research program to seek maximum efficiency and effectiveness in the control of phosphorus introductions into the Great Lakes.

3. The following table establishes phosphorus loads for the base year (1976) and future phosphorus loads. The Parties, in cooperation with the State and Provincial Governments, shall within eighteen months after the date of entry into force of this Agreement confirm the future phosphorus loads, and based on these establish load allocations and compliance schedules, taking into account the recommendations of the International Joint Commission arising from the Pollution from Land Use Activities Reference. Until such loading allocations and compliance schedules are established, the Parties agree to maintain the programs and other measures specified in Annex 2 of the Great Lakes Water Quality Agreement of 1972.

Basin 1976 Phosphorus

Load in Metric Tonnes

Per Year Future

Phosphorus Load

in Metric Tonnes

Per Year Lake Superior 36003400* Lake Michigan 67005600* Main Lake Huron 30002800 Georgian

Bay 630600* North Channel 550520* Saginaw Bay 870440* Lake Erie 2000011000** Lake

Ontario 110007000**

* These loadings would result if all municipal plants over one million gallons per day achieved an effluent of 1 milligram per litre of phosphorus.

** These loadings are required to meet the goals stated in paragraph 1 above.

AGREEMENT BETWEEN THE UNITED STATES OF AMERICA AND CANADA ON GREAT LAKES WATER QUALITY

1. The purpose of this Supplement is to outline measures to fulfill the commitments undertaken pursuant to paragraph 3 of Annex 3 of the 1978 Great Lakes Water Quality Agreement which requires that:

"... The Parties, in cooperation with the State and Provincial Governments, shall within eighteen months after the date of entry into force of this Agreement confirm the future phosphorus loads, and based on these establish load allocations and compliance schedules, taking into account the recommendations of the International Joint Commission arising from the Pollution from Land Use Activities Reference ..."

Phosphorus Target Loads 2. Table 1 establishes the recommended phosphorus target loads which represent planning guides for the Parties. Table 1 replaces the table contained in paragraph 3 of Annex 3 of the 1978 Great Lakes Water Quality Agreement (GLWQA).

Table 1

BASIN	Phosphorus Target Loads (metric tonnes per year)
Lake Superior	(See Section 3(b))
Lake Michigan	"
Main Lake Huron	"
Georgian Bay	"
North Channel	"
Saginaw Bay	440 (Note 1)
Lake Erie	11000 (Note 2)
Lake Ontario	7000 (Note 2)

Note 1 Target load designed to alleviate drinking water taste and odour problems. Note 2 Target loads proposed to meet ecosystem objectives in Annex 3. The allocation of the phosphorus target loads between the two countries shall be consistent with the equal rights of both Parties in the use of their boundary waters.

3. Phosphorus Load Reductions

(a) Lower Lakes: Table 2 summarizes the estimated phosphorus loading that will be discharged to the Lower Lakes basins when all municipal waste treatment facilities over one million gallons per day achieve compliance with the one milligram per litre (1 mg/l) effluent concentration (on a monthly average basis) as required by Article VI, 1(a) of the 1978 GLWQA. The table also shows the further reductions required to meet the Phosphorus Target Loads.

Table 2 - Phosphorus Load Reduction Targets - metric tonnes per year

Basin	Estimated Loadings at 1 mg/l (Note 1) Phosphorus Target Load	Estimates of Further Reductions Required
Lake Erie	13,000	11,000
		2,000
Lake Ontario	7,430	7,000
		430

Note 1 Estimated loading when all municipal waste treatment facilities over one million gallons/day achieve 1 mg/l phosphorus effluent target levels.

(b)Upper Lakes:Load reductions for the Upper Lakes will be accomplished by achieving the 1 mg/l phosphorus effluent concentration (on a monthly average) at municipal waste treatment facilities discharging more than one million gallons per day. The Parties further agree to maintain the present oligotrophic state of the open waters and relative algal biomass of Lakes Superior and Huron. In addition, the United States agrees to undertake efforts to achieve the substantial elimination of algal nuisance growths in Lake Michigan. Further measures will be implemented as required for Saginaw Bay, various localized nearshore problem areas and Green Bay.(c)Table 3 presents the distribution of further reductions in phosphorus loading required for Lake Erie (in metric tonnes/year) in order to achieve the estimated target loads. These figures will be used by the Parties in the development of detailed plans for achieving further phosphorus reductions as described in 4(a) and (b) below.

Table 3 - Allocation of reductions to meet target loads for Lake Erie as shown in Table 1

CANADA U.S. TOTAL 3001700 2000

(d)For Lake Ontario, the Parties, in cooperation and full consultation with State and Provincial

Governments, agree to review the measures to achieve further phosphorus reductions in this Basin and will, within one year, meet to allocate the further phosphorus reductions between the parties. Plans to achieve the required reductions set out in Table 2 will be developed using these figures in accordance with procedures described in 4(a) and (b) below.

4. Phosphorus Load Reduction Plans

(a) Phosphorus load reduction plans will be developed and implemented by the Parties in cooperation and full consultation with State and Provincial governments to achieve the phosphorus reductions for Lake Erie and Ontario described in Table 2. The plans will include phosphorus control programs and other measures as outlined in Section 5 and will describe any additional measures which will be undertaken to evaluate and review progress in achieving the phosphorus load reductions. A staged approach, incorporating target dates for achieving further reductions, will be included in the plans to provide the Parties and State and Provincial governments with a framework for implementing and evaluating the effectiveness of controls.

(b) These detailed plans shall be tabled by the Parties with the International Joint Commission 18 months after agreement on this Supplement to Annex 3. The Parties will provide the Commission with progress reports and annual updates of these plans.

5. Programs and Other Measures

The following phosphorus control programs and measures will be developed and implemented by the Parties in cooperation and full consultation with State and Provincial governments to achieve the required reductions in accordance with the plans developed pursuant to Section 4. The Parties recognize that the responsibility for the control on nonpoint sources is shared between the Parties and the State and Provincial governments.

(a) Municipal Waste Treatment Facilities

(i) Priority will be given to the continuation and intensification of efforts to ensure that municipal waste treatment facilities discharging more than one million gallons per day achieve an effluent concentration of 1 mg/l total phosphorus on a monthly average.

(ii) Where necessary, consideration will be given to operating facilities capable of greater phosphorus reduction at higher level of phosphorus removal than that required in 5(a)(i).

(iii) Where necessary, municipal waste treatment facilities designed, built, expanded or modified after October 1, 1983 should allow for later modification to provide for greater removal of phosphorus than that required under 5

(a)(i)(b) **Detergent Phosphorus Limitation** Priority will be given to continuing efforts to limit phosphorus in household detergents.

(c) **Industrial Discharges** Reasonable and practical measures will be undertaken to control industrial sources of phosphorus.

(d) **Nonpoint Source Programs and Measures** Priority management areas will be identified and designated for application of urban and agricultural programs and measures which include:

(i) **Urban drainage management control programs** where feasible consisting of level 1 measures throughout the Great Lakes Basin; and level 2 measures where necessary to achieve reductions or where local environmental conditions dictate (Note 1); and

(ii) **Agricultural nonpoint source management programs** where feasible consisting of level 1 measures throughout the Basin and level 2 measures where necessary to achieve reductions of where local environmental conditions dictate (Note 1).

Note 1: Level 1 nonpoint source control options include:

Agricultural: adoption of management practices such as: animal husbandry control measures, crop residue management, conservation tillage, no-till, winter cover-crops, crop rotation, strip cropping, vegetated buffer strips along stream and ditch banks, and improved fertilizer management practices.

Urban: adoption of management practices such as: erosion controls, use of natural storage capacities and street cleaning.

Level 2 nonpoint source controls include Level 1 plus:

Agricultural: adoption of intensive practices such as: contour plowing, contour strip cropping, contour diversions, tile outlet-terraces, flow control structures, grassed waterways, sedimentation basins and livestock manure storage

facilities. Urban: adoption of practices such as: artificial detention and sedimentation of stormwater and runoff and reduction of phosphorus in combined sewer overflows. (e) Research Pursuant to the provisions of paragraph 2(e) of Annex 3, the Parties will make special efforts to assure that their research activities will be responsive to the Programs and Other Measures described herein. (f) Monitoring and Surveillance The Parties will develop and implement surveillance and monitoring measures to determine the progress of Phosphorus Load Reduction Plans for the Lower Lakes as called for under Section 4 above, and to evaluate efforts taken by the Parties to reduce phosphorus in the Great Lakes Basin. These measures will include an inventory of areas treated, watershed modelling and improved measurement of tributary loadings to the Lower Lakes for the purpose of providing improved nonpoint source loading estimates and the monitoring of mass loadings to the Upper Lakes to maintain or improve the environmental conditions described in Section 3(b). 6. Review The Parties shall meet no later than December 31, 1988, to review the effectiveness of the programs and measures described herein, and any remaining load reduction measures required to achieve the target loads.

ANNEX 4 - DISCHARGES OF OIL AND HAZARDOUS POLLUTING SUBSTANCES FROM VESSELS

1. Definition. As used in this Annex:

(a) "Discharge" includes, but is not limited to, any spilling, leaking, pumping, pouring, emitting or dumping; it does not include unavoidable direct discharges of oil from a properly functioning vessel engine; (b) "Harmful quantity of oil" means any quantity of oil that, if discharged from a ship

that is stationary into clear calm water on a clear day, would produce a film or a sheen upon, or discolouration of, the surface of the water or adjoining shoreline, or that would cause a sludge or emission to be deposited beneath the surface of the water or upon the adjoining shoreline;(c)"Oil" means oil of any kind or in any form, including, but not limited to, petroleum, fuel oil, oil sludge, oil refuse, oil mixed with ballast or bilge water and oil mixed with wastes other than dredged material;(d)"Tanker" means any vessel designed for the carriage of liquid cargo in bulk; and(e)"Vessel" means any ship, barge or other floating craft, where or not self-propelled.

2. General Principles. Compatible regulation shall be adopted for the prevention of discharges into the Great Lakes System of harmful quantities of oil and hazardous polluting substances from vessels in accordance with the following principles;

(a)The discharge of a harmful quantity of oil or hazardous polluting substance, including any such quantities as may be contained in ballast water,shall be prohibited and made subject to appropriate penalties; and(b)As soon as any person in charge has knowledge of any discharge, or probable discharge, of harmful quantities of oil or hazardous polluting substances, immediate notice of such discharge shall be given to the appropriate agency in the jurisdiction where the discharge occurs; failure to give this notice shall be made subject to appropriate penalties.

3. Oil. The programs and measures to be adopted for the prevention of discharges of harmful quantities of oil shall include;

(a)Compatible regulations for design, construction, and operation of vessels based on the following principles.

(i)Each vessel shall have a suitable means of containing on board cargo oil spills caused by loading or unloading operations;(ii)Each vessel shall have a suitable means of containing on board fuel oils spills caused by loading or unloading operations, including those from tank vents and overflow pipes;(iii)Each vessel shall have the capability of retaining on board oily wastes accumulated during vessel operation;(iv)Each vessel shall be capable of off-loading retained oily wastes to a reception facility;(v)Each vessel shall be provided with a means for rapidly and safely stopping the flow of cargo or fuel oil during loading, unloading or bunkering operations in the event of an emergency;(vi)Each vessel shall be provided with suitable lighting to adequately illuminate all cargo and fuel oil handling areas if the loading, unloading or bunkering operations occur at night;(vii)Hose assemblies used on board vessels for oil loading, unloading, or bunkering shall be suitably designed, identified, and inspected to minimize the possibility of failure; and(viii)Oil loading, unloading, and bunkering systems shall be suitably designed, identified, and inspected to minimize the possibility of failure; and(b) Programs to ensure that merchant vessel personnel are trained in all functions involved in the use, handling, and stowage of oil and in procedures for abatement of oil pollution.

4. Hazardous Polluting Substances. The programs and measures to be adopted for the prevention of discharges of harmful quantities of hazardous polluting substances carried as cargo shall include:

(a)Compatible regulations for the design, construction, and operation of vessels using as a guide the standards developed by the International Maritime Organizations (IMO), including the following additional requirements:

(i)Each vessel shall have a suitable means of containing on board spills caused by loading or unloading operations;(ii)Each vessel shall have a capability of retaining on board wastes accumulated during vessel operation;(iii) Each vessel shall be capable of off-loading wastes retained to a reception facility;(iv)Each vessel shall be provided with a means for rapidly and safely stopping the flow during loading or unloading operations in the event of an emergency; and(v)Each vessel shall be provided with suitable lighting to adequately illuminate all cargo

handling areas if the loading or unloading operations occur at night;(b)Identification of vessels carrying cargoes of hazardous polluting substances in bulk, containers, and package form, and of all such cargoes;(c)Identification in vessel manifests of all hazardous polluting substances;(d)Carriage and storage arrangements of all hazardous polluting substances in packaged form using as a guide the International Maritime Dangerous Goods Code; and(e)Programs to ensure that merchant vessel personnel are trained in all functions involving the use, handling, and stowage of hazardous polluting substances; the abatement of pollution from such substances; and the hazards associated with the handling of such substances.

5. Additional Measures. Both Parties, in cooperation with State and Provincial Governments shall take, as appropriate, action to ensure the provision of adequate facilities for the reception, treatment, and subsequent disposal of oil and hazardous polluting substances wastes from all vessels.

ANNEX 5 - DISCHARGES OF VESSEL WASTES

1. Definitions. As used in this Annex:

(a) "Discharge" includes, but is not limited to, any spilling, leaking, pumping, emitting, and dumping;(b)"Garbage" means all kinds of victual, domestic, and operational wastes, excluding fresh fish and parts thereof generated during the normal operation of the ship and liable to be disposed of continually or periodically;(c)"Sewage" means human or animal waste generated on board ship and includes wastes from water closets, urinals, or a hospital facility;(d) "Vessel" means any ship, barge or other floating craft, whether or not self-propelled; and(e) "Waste water" means water in combination with other substances, including ballast water and water used for washing cargo holds, but excluding water in combination with oil, hazardous polluting substances, or sewage.

2. General Principles. Compatible regulations shall be adopted governing the discharge into the Great Lakes System of garbage, sewage, and waste water from vessels in accordance with the following principles:

(a)The discharge of garbage shall be prohibited and made subject to appropriate penalties;(b) The discharge of waste water in harmful amounts or concentrations shall be prohibited and made subject to appropriate penalties; and(c)Every vessel operating in these waters that is provided with toilet facilities shall be equipped with a device or devices to contain, incinerate, or treat sewage to an adequate degree; appropriate penalties shall be provided for failure to comply with the regulation.

3. Critical Use Areas. Critical use areas of the Great Lakes System may be designate where the discharge of waste water or sewage shall be limited of prohibited.

4. The Parties, in cooperation with State and Provincial Governments, shall establish regulation to control the discharge of sewage from pleasure craft of other classes of vessels operating in the Great Lakes System or designated areas thereof.

5. Additional Measures. The Parties shall take, as appropriate, action to ensure the provision of adequate facilities for the reception, treatment, and subsequent disposal of garbage, waste water, and sewage from all vessels.

ANNEX 6 - REVIEW OF POLLUTION FROM SHIPPING SOURCES

1. Review. The Canadian Coast Guard and the United States Coast Guard shall continue to review services, systems, programs, recommendations, standards and regulations relating to shipping activities for the purpose of maintaining or improving Great Lakes water quality. The reviews shall include:

(a) Review of vessel equipment, vessel manning, and navigation practices or procedures, and of aids to navigation and vessel traffic management, for the purpose of precluding casualties which may be deleterious to water quality; (b) Review of practices and procedures regarding waste water and their deleterious effect on water quality, including, as required, studies to determine if live fish or invertebrates in ballast water discharges into the Great Lakes System constitute a threat to

the System;(c)Review of practices and procedures, as well as current technology for the treatment of vessel sewage;(d)Review of current practices and procedures regarding the prevention of pollution from the loading, or unloading, or on board transfer of cargo; and(e)Review of international ship safety, pollution prevention and civil liability conventions and standards developed by the International Maritime Organization to determine their applicability in the boundary waters of the Great Lakes System

2. Consultation. Representatives of the Canadian Coast Guard and the United States Coast Guard, and other interested agencies, shall meet at least annually to consider Annexes 4, 5, 6, 8 and 9 of this Agreement. A report of this annual consultation shall be furnished to the International Joint Commission prior to its annual meeting on Great Lakes water quality. The purpose of the consultation shall be to:

(a)Provide an interchange of information with respect to continuing reviews, ongoing studies, and areas of concern;(b)Identify and determine the relative importance of problems requiring further study; and(c) Apportion responsibility, as between the Canadian Coast Guard and the United States Coast Guard, for the studies, or portions thereof, which were identified in subparagraph 2(b) above.

3. Studies. Where a review identifies additional areas for improvement, the Canadian Coast Guard and the United States Coast Guard, and other interested agencies, will undertake a study to establish improved procedures for the abatement and control of pollution from shipping sources, and will:

(a)Develop a brief study description which will include the nature of the perceived problem, procedures to quantify the problem, alternative solutions to the problem, procedures to determine

the best alternative, and an estimated completion date;(b) Transmit study descriptions to the International Joint Commission and other interested agencies;(c)Transmit the study, or a brief summary of its conclusions, to the International Joint Commission and other interested agencies; and(d)Transmit a brief status report to the International Joint Commission and other interested agencies if the study is not completed by the estimated completion date.

4. Responsibility. Responsibility for the coordination of the review, consultation, and studies is assigned to the Canadian Coast Guard and the United States Coast Guard.

ANNEX 7 - DREDGING

1. There shall be established, under the auspices of the Water Quality Board, a Subcommittee on Dredging. The Subcommittee shall:

(a)Review the existing practices in both countries relating to dredging activities, as well as the previous work done by the International Working Group on Dredging, with the objective of developing, within one year of the date of entry into force of this Agreement, compatible guidelines and criteria for dredging activities in the boundary waters of the Great Lakes System;(b)Maintain a register of significant dredging projects being undertaken in the Great Lakes System with information to allow for the assessment of the environmental effects of the projects. The register shall include pertinent statistics to allow for the assessment of pollution loadings from dredged materials to the Great Lakes System;(c)Encourage the exchange of information relating to developments of dredging technology and environmental research.

2. The Subcommittee shall identify specific criteria for the classification of polluted sediments of designated areas of intensive and continuing dredging activities within the Great Lakes System. Pending development of criteria and guidelines by the Subcommittee, and their acceptance of the Parties, the Parties shall continue to apply the criteria now in use by the regulatory authorities; however, neither party shall be precluded from applying standards more stringent than those now in use.

3. The Parties shall continue to direct particular attention to the identification and preservation of significant wetland areas in the Great Lakes Basin Ecosystem which are threatened by dredging and disposal activities.

4. The Parties shall encourage research and investigate advances in dredging technology and the pathways, fate and effects of nutrients and contaminants of dredged materials.

5. The Subcommittee shall undertake any other activities as the Water Quality Board may direct.

ANNEX 8 - DISCHARGES FROM ONSHORE AND OFFSHORE FACILITIES

1. Definitions. As used in this Annex:

(a)"Discharge" means the introduction of polluting substances into receiving waters and includes, but is not limited to, any spilling, leaking, pumping, pouring, emitting or dumping; it does not include continuous effluent discharges from municipal or industrial treatment facilities;(b)"Harmful quantity of oil" means any quantity of oil that, if discharged into clear calm waters on a clear day, would produce a film or sheen upon, or discoloration of the surface of the water or adjoining shoreline, or that would cause a sludge or emulsion to be deposited beneath the surface of the water or upon the adjoining shoreline;(c) "Facility" includes motor vehicles, rolling stock, pipelines, and any other facility that is used or capable of being used for the purpose of processing, producing, storing, disposing, transferring or transporting oil or hazardous polluting substances, but excludes vessels;(d)"Offshore facility" means any facility of any kind located in, on or under any water;(e)"Onshore facility" means any facility of any kind located in, on or under, any land other than submerged land;(f)"Oil" means oil of any kind or in any form, include, but not limited to petroleum, fuel oil, oil sludge, oil refuse, and oil mixed with wastes, but does not include constituents of dredged spoil.

2. Principles. Regulations shall be adopted for the prevention of discharges into the Great Lakes System of harmful quantities of oil and hazardous polluting substances from onshore and offshore facilities in accordance with the following principles:

(a) Discharges of harmful quantities of oil or hazardous polluting substances shall be prohibited and made subject to appropriate penalties; (b) As soon as any person in charge has knowledge of any discharge of harmful quantities of oil or hazardous polluting substances, immediate notice of such discharge shall be given to the appropriate agency in the jurisdiction where the discharge occurs; failure to give this notice shall be made subject to appropriate penalties.

3. Programs and Measures. The programs and measures to be adopted shall include the following:

(a) Review of the design, construction, and location of both existing and new facilities for their adequacy to prevent the discharge of oil or hazardous polluting substances; (b) Review of the operation, maintenance and inspection procedures of facilities for their adequacy to prevent the discharge of oil or hazardous polluting substances; (c) Development and implementation of regulations and personnel training programs to ensure the safe use and handling of oil or hazardous polluting substances; (d) Programs to ensure that at each facility plans and provisions are made and equipment provided to stop rapidly and safely, contain, and clean up discharges of oil or hazardous polluting substances; and (e) Compatible regulations and other programs for the identification and placarding of containers, vehicles and other facilities containing, carrying, or handling oil or hazardous polluting substances; and where appropriate notification to appropriate agencies of vehicle movements, maintenance of a registry, and identification in manifests of such substances to be carried.

4. Implementation.

(a) Each Party shall submit a report to the International Joint Commission outlining its programs and measures, existing or proposed, for the implementation of this Annex within six months of the date of entry into force of this Agreement. (b) The report shall outline programs and measures, existing or proposed, for each of the following types of onshore and offshore facilities: (i) land transportation including rail and road modes; (ii) pipelines on land and submerged under water; (iii) offshore drilling rigs and wells; (iv) storage facilities both onshore and offshore; and (v) wharves and terminals with trestle or underwater pipeway connections to land and offshore island type structures and buoys used for the handling of oil and hazardous polluting substances. (c) The report shall outline programs and measures, existing or proposed, for any other type of onshore or offshore facility. (d) Upon receipt of the reports, the Commission, in

consultation with the Parties, shall review the programs and measures outlined for adequacy and compatibility and, if necessary, make recommendation to rectify any such inadequacy or incompatibility it finds.

ANNEX 9 - JOINT CONTINGENCY PLAN

1. The Plan. Annex one (CANUSLAK) of the Canada-United States Joint Marine Contingency Plan, as amended or reviewed, shall be maintained in force for the Great Lakes. The Canadian Coast Guard and the United States Coast Guard shall, in cooperation with other affected parties, identify and provide detailed Supplements for areas of high risk and of particular concern in augmentation of CANUSLAK. It shall be the responsibility of the United States Coast Guard and the Canadian Coast Guard to coordinate and to maintain the Plan and the Supplements appended thereto.

2. Purpose. The purpose of the Plan is to provide for coordinated and integrated response to pollution incidents in the Great Lakes System by responsible federal, state, provincial and local agencies. the Plan supplements the national, provincial and regional plans of the Parties.

3. Pollution Incidents..

(a) A pollution incident is a discharge, or an imminent threat of discharge of oil, hazardous polluting substance or other substance of such magnitude or significance as to require immediate response to contain, clean up, and dispose of the material (b) The objectives of the Plan in pollution incidents are:

(i) To develop appropriate preparedness measures and effective systems for discovery and reporting the existence of a pollution incident within the area covered by the Plan; (ii) To institute prompt measures to restrict the further spread of the pollutant; and (iii) To provide adequate cleanup response to pollution incidents.

4. Funding. The costs of operations of both Parties under the Plan shall be borne by the Party in whose waters the pollution incident occurred, unless otherwise agreed.

5. Amendment. The Canadian Coast Guard and the United States Coast Guard are empowered to amend the Plan subject to the requirement that such amendments shall be consistent with the purpose and objectives of this Annex.

ANNEX 10 - HAZARDOUS POLLUTING SUBSTANCES

1. The Parties shall:

(a) Maintain a list, to be known as Appendix 1 of the Annex (hereinafter referred to as Appendix 1), of the substances known to have toxic effects on aquatic and animal life and a risk of being discharged to the Great Lakes System; (b) Maintain a list, to be known as Appendix 2 of this Annex (hereinafter referred to as Appendix 2), of substances potentially having such effects and such a risk of discharge, and to give priority to the examination of these substances for possible transfer to Appendix 1; (c) Ensure that these lists are continually revised in the light of growing scientific knowledge; and (d) Develop and implement programs and measures to minimize or eliminate the risk of release of hazardous polluting substances to the Great Lakes System.

2. Hazardous polluting substances to be listed in Appendix 1 shall be determined in accordance with the following procedures:

(a) Selection of all hazardous substances for listing in Appendix 1 shall be based upon documented toxicological and discharge potential data which have been evaluated by the Parties and deemed to be mutually acceptable. (b) Revisions to Appendix 1 may be made by mutual consent of the Parties and shall be treated as amendments to this Annex for the purposes of Article XIII of this Agreement. (c) Using the agreed selection criteria, either Party may recommend at any time a substance to be added to the list in Appendix 1. Such substance need not previously have been listed in Appendix 2. The Party receiving the recommendation will have 60 days to review the associated documentation and either reject the proposed substance or accept the substance pending completion of appropriate procedural or domestic regulatory requirements. Cause for rejection

must be documented and submitted to the initiating Party and may be the basis for any further negotiations.

3. The criteria to be applied to the selection of substances as candidates for listing in Appendix 1 are:

(a) Acute toxicological effects, as determined by whether the substance is lethal to:

(i) One-half of a test population of aquatic animals in 96 hours or less at a concentration of 500 milligrams per litre or less; or (ii) One-half of a test population of animals in 14 days or less when administered in a single oral dose equal to or less than 50 milligrams per kilogram of body weight; or (iii) One-half of a test population of animals in 14 days or less when dermally exposed to an amount equal to or less than 200 milligrams per kilogram body weight for 24 hours; or (iv) One-half of a test population of animals in 14 days or less when exposed to a vapour concentration equal to or less than 20 cubic centimetres per cubic meter in air for one hour; or (v) Aquatic flora as measured by a maximum specific growth rate or total yield of biomass which is 50 per cent lower than a control culture over 14 days in medium at concentrations equal to or less than 100 milligrams per litre.

(b) Risk of discharge into the Great Lakes System, as determined by:

(i) Gathering information on the history of discharges or accidents; (ii) Assessing the modal risks during transport and determining the use and distribution patterns; (iii) Identifying quantities manufactured or imported.

4. Potentially hazardous polluting substances to be listed in Appendix 2 of this Annex shall be determined in accordance with the following procedures:

(a) Either Party may add new substances to Appendix 2 by notifying the other in writing that the substance is considered to be a potential hazard because of documented information concerning aquatic toxicity mammalian and other vertebrate toxicity, phytotoxicity, persistence, bio-accumulation, mutagenicity, teratogenicity, carcinogenicity, environmental translocation or because of documented information on risk of discharge to the environment. The documentation of the potential hazard and the selected criteria upon which it is based will also be submitted. (b) Removal of substances from Appendix 2 shall be by mutual consent of the Parties. (c) The Parties shall give priority to the examination of substances listed in Appendix 2 for possible transfer to Appendix 1.

5. Programs and measures to control the risk of pollution from transport, storage, handling and disposal of hazardous polluting substances are contained in Annexes 4 and 8; and

6. In addition to the lists of hazardous polluting substances described in Appendices 1 and 2 to this Annex, practice and procedures consistent with the general principles of this Agreement shall be applied to those substances categorized as marine pollutants by the International Maritime Organization.

APPENDIX 1 - HAZARDOUS POLLUTING SUBSTANCES

AcetaldehydeAcetic AcidAcetic AnhydrideAcetone CyanohydrinAcetyl BromideAcetyl
 ChlorideAcroleinAcrylonitrileAldrinAllyl AlcoholAllyl ChlorideAluminum
 SulfateAmmoniaAmmonium AcetateAmmonium BenzoateAmmonium BicarbonateAmmonium
 BichromateAmmonium BifluorideAmmonium BisulfiteAmmonium CarbamateAmmonium
 Carbonate Ammonium ChlorideAmmonium ChromateAmmonium Citrate, DibasicAmmonium
 FluoborateAmmonium FluorideAmmonium HydroxideAmmonium Oxalate Ammonium
 SilicofluorideAmmonium SulfamateAmmonium SulfideAmmonium SulfiteAmmonium
 TartrateAmmonium Thiocyanate Ammonium Thiosulfate Amyl Acetate AnilineAntimony
 PentachlorideAntimony Potassium TartrateAntimony TribromideAntimony TrichlorideAntimony
 TrifluorideAntimony TrioxideArsenic DisulfideArsenic PentoxideArsenic TrichlorideArsenic
 TrioxideArsenic TrisulphideBarium CyanideBenzeneBenzoic AcidBenzonitrileBenzoyl
 ChlorideBenzyl ChlorideBeryllium ChlorideBeryllium FluorideBeryllium NitrateButyl
 AcetateButylamineButyric AcidCadmium AcetateCadmium BromideCadmium ChlorideCalcium
 ArsenateCalcium ArseniteCalcium CarbideCalcium ChromateCalcium CyanideCalcium
 DodecylbenzenesulfonateCalcium HydroxideCalcium HypochloriteCalcium
 OxideCaptanCarbarylCarbon
 DisulfideChlordaneChlorineChlorobenzeneChloroformChlorosulfonic AcidChlorpyrifosChromic
 AcetateChromic AcidChromic SulfateChromous ChlorideCobaltous BromideCobaltous
 ForemateCobaltous SulfamateCoumaphosCresolCupric AcetateCupric AcetoarseniteCupric
 ChlorideCupric NitrateCupric OxalateCupric SulfateCupric Sulfate, AmmoniatedCupric
 TartrateCyanogen ChlorideCyclohexane2, 4-D Acid2, 4-D
 EstersDalaponDDTDiazinonDicambaDichlobenilDichloneDichlorvosDieldrinDiethylamineDimet
 hylamine Dinitrobenzene (mixed)DinitrophenolDiquatDisulfotonDiuronDedocylbenzenesulfonic
 AcidEndosulfanEndrinEthionEthylbenzeneEthylenediamineEDTAFerric Ammonium CitrateFerric
 Ammonium OxalateFerric ChlorideFerric Fluoride Ferric NitrateFerric SulfateFerrous
 Ammonium SulfateFerrous ChlorideFerrous SulfateFormaldehydeFormic AcidFumaric
 AcidFurfuralGuthionHeptachlorHydrochloric AcidHydrofluoric AcidHydrogen
 CyanideIsopreneIsopropanolamine DodecylbenzenesulfonateKelthaneLead AcetateLead
 ArsenateLead ChlorideLead FluoborateLead FluorideLead IodideLead NitrateLead Stearate Lead
 SulfateLead SulfideLead ThiocyanateLindaneLithium ChromateMalathionMaleic AcidMaleic
 AnhydrideMercuric CyanideMercuric NitrateMercuric SulfateMercuric ThiocyanateMercurous
 NitrateMethoxychlorMethyl MercaptanMethyl MethacrylateMethyl
 ParathionMevinphosMexacarbamateMonoethylamineMonomethylamineNaledNaphthaleneNaphtenic
 AcidNickel Ammonium SulfateNickel ChlorideNickel HydroxideNickel NitrateNickel
 SulfateNitric AcidNitrobenzeneNitrogen DioxideNitrophenol

(mixed) Paraformaldehyde Parathion Pentachlorophenol Phenol Phosgene Phosphoric
 Acid Phosphorous Phosphorus Oxycnloride Phosphorus Pentasulfide Phosphorus
 Trichloride Polychlorinated Biphenyls Potassium Arsenate Potassium Arsenite Potassium
 Bichromate Potassium Chromate Potassium Cyanide Potassium Hydroxide Potassium
 Permanganate Propionic Acid Propionic Anhydride Pyrethrins Quinoline Resorcinol Selenium
 Oxide Sodium Sodium Arsenate Sodium Arsenite Sodium Bichromate Sodium Bifluoride Sodium
 Bisulfite Sodium Chromate Sodium Cyanide Sodium Dodecylbenzenesulfonate Sodium
 Fluoride Sodium Hydrosulfide Sodium Hydroxide Sodium Hypochlorite Sodium Methylate Sodium
 Nitrite Sodium Phosphate, Dibasic Sodium Phosphate, Tribasic Sodium Selenite Strontium
 Chromate Strychnine Styrene Sulfuric Acid Sulfur Monochloride 2,4,5-T Acid 2,4,5-7
 Esters TDE Tetraethyl Lead Tetraethyl
 Pyrophosphate Toluene Toxaphene Trichlorfon Trichlorophenol Triethanolamine
 Dodecylbenzenesulfonate Triethylamine Thrimethylamine Uranyl Acetate Uranyl Nitrate Vanadium
 Pentoxide Vanadyl Sulfate Vinyl Acetate Xylene (mixed) Xylenol Zinc Acetate Zinc Ammonium
 Chloride Zinc Borate Zinc Bromide Zinc Carbonate Zinc Chloride Zinc Cyanide Zinc Fluoride Zinc
 Formate Zinc Hydrosulfite Zinc Nitrate Zinc Phenolsulfonate Zinc Phosphide Zinc Silicofluoride Zinc
 Sulfate Zirconium Nitrate Zirconium Potassium Fluoride Zirconium Sulfate Zirconium Tetrachloride

APPENDIX 2 - POTENTIAL HAZARDOUS POLLUTING SUBSTANCES

Acridine Allethrin Aluminum Fluoride Aluminum Nitrate Ammonium Bromide Ammonium
 Hypophosphite Ammonium Iodide Ammonium Pentaborate Ammonium Persulfate Antimony
 Pentafluoride Antimycin A Arsenic Acid Barhan Benfluralin Bensulide Benzene
 Hexachloride Beryllium Sulfate Butifos Cadmium Cadmium Cyanide Cadmium
 Nitrate Captafol Carbophenothion Chlorflurazole Chlorothion Chlorpropham Chromic
 Chloride Chromium Chromyl Chloride Cobaltous Fluoride Copper Crotoxyphos Cupric
 Carbonate Cupric Citrate Cupric Formate Cupric Glycinate Cupric Lactate Cupric Paraamino
 Benzoate Cupric Salicylate Cupric Subacetate Cuprous Bromide Demeton Dibutyl
 Phthalate Dicapthon 2,4-Dinitrochlorobenzene p-Dinitrocresol Dinocap Dinoseb Dioxathion Dodine EP
 NGold Trichloride Hexachlorophene Hydrogen Sulfide m-Hydroxybenzoic Acid p-Hydroxybenzoic
 Acid Hydroxylamine 2-Hydroxyphenazine-1-Carboxylic Acid Lactonitrile Lead Tetraacetate Lead
 Thiosulfate Lead Tungstate Lithium Bichromate Malachite Green Manganese Chloride,
 Anhydrous MCPA Mercuric Acetate Mercuric

ChlorideMercuryMetam-Sodiump-Methylamino-Phenol2-Methyl-NapthoquinoneNeburonNickel
 FormatePhenylmercuric Acetaten-Phenyl NaphthylaminePhoratePhosphamidonPicloramPotassium
 AzidePotassium CuprocyanidePotassium FerricyanidePropyl AlcoholPyridyl Mercuric
 AcetateRotenoneSilverSilver NitrateSilver SulfateSodium AzideSodium
 2-Chlorotoluene-5-SulfonateSodium PentachlorophenateSodium Phosphate, MonobasicSodium
 SulfideStannous FluorideStrontium
 NitrateSulfoxideTemephosThalliumThionazin1,2,4-TrichlorobenzeneUranium PeroxideUranyl
 SulfateZinc BichromateZinc Potassium ChromateZirconium AcetateZirconium Oxychloride

ANNEX 11 - SURVEILLANCE AND MONITORING

1. Surveillance and monitoring activities shall be undertaken for the following purposes:

(a)Compliance. To assess the degree to which jurisdictional control requirements are being met.(b)Achievement of General and Specific Objectives. To provide definitive information on the location, severity, areal or volume extent, frequency and duration of non-achievement of the Objectives, as a basis for determining the need for more stringent control requirements.(c)Evaluation of Water Quality Trends. To provide information for measuring local and whole lake response to control measures using trend analysis and cause/effect relationships, and to provide information which will assist in the development and application of predictive techniques for assessing impact of new developments and pollution sources. The results of water quality evaluations will be used for:

(i)assessing the effectiveness of remedial and preventative measures and identifying the need for the improved pollution control;(ii)assessing enforcement and management strategies; and(iii)identifying the need for further technology development and research

activities.(d)Identification of Emerging Problems. To determine the presence of new or hitherto detected problems in the Great Lakes Basin Ecosystem, leading to the development and implementation of appropriate pollution control measures.(e)Annex 2 Programs. To support the development of Remedial Action Plans for Areas of Concern and Lakewide Management Plans for Critical Pollutants pursuant to Annex 2.2. A joint surveillance and monitoring program necessary to ensure the attainment of the foregoing purposes shall be developed and implemented among the Parties and the State and Provincial Governments. The Great Lakes International Surveillance Plan contained in the Water Quality Board Annual Report of 1975 and revised in subsequent reports shall serve as a model for the development of the joint surveillance and monitoring program.3.The

program shall include baseline data collection, sample analysis, evaluation and quality assurance programs (including standard sampling and analytical methodology, inter-laboratory comparisons, and compatible data management) to allow assessment of the following:

(a)Inputs from tributaries, point source discharges, atmosphere, and connecting channels;(b) Whole lake data including that for nearshore areas (such as harbours and embayments, general shoreline and cladophora growth areas), open waters of the Lakes, fish contaminants, and wildlife contaminants;(c)Overflows including connecting channels, water intakes and outlets;(d)Total pollutant loadings to, storage and transformation within, and export from the Great Lakes System;(e)The adequacy of proposed load reductions and schedules contained in Lakewide Management Plans; and(f) Contributions of various exposure media to the overall human intake of toxic substances in the Great Lakes Basin Ecosystem.4. Development of Ecosystem Health Indicators for the Great Lakes. The Parties agree to develop ecosystem health indicators to assist in evaluating the achievement of the specific objectives for the ecosystem pursuant to Annex 1: (a) with respect to Lake Superior, lake trout and the crustacean *Pontoporeia hoyi* shall be used as indicators:

Lake Trout-productivity greater than 0.38 kilograms/hectare;-stable, self-producing stocks;-free from contaminants at concentrations that adversely affect the trout themselves or the quality of the harvested products.*Pontoporeia hoyi*-the abundance of the crustacean, *Pontoporeia hoyi*, maintained throughout the entire lake at present levels of 220-320/(metres)² (depths less than 100 metres) and 30-160/(metres)² (depths greater than 100 metres); and(b)with respect to the rest of the boundary waters of the Great Lakes System or portions thereof, and for Lake Michigan, the indicators are to be developed.

ANNEX 12 - PERSISTENT TOXIC SUBSTANCES

1. Definitions. As used in this Annex:

(a)"Persistent toxic substance" means any toxic substance with a half-life in water of greater than eight weeks;(b)"Half-life" means the time required for the concentration of a substance to diminish to one-half of its original value in a lake or water body;(c)"Early warning system" means a procedure to anticipate future environmental contaminants (i.e., substances having an adverse effect on human health or the environment) and to set priorities for environmental research, monitoring and regulatory action.2. General Principles.

(a)Regulatory strategies for controlling or preventing the input of persistent toxic substances to the

Great Lakes System shall be adopted in accordance with the following principles:

(i)The intent of programs specified in this Annex is to virtually eliminate the input of persistent toxic substances in order to protect human health and to ensure the continued health and productivity of living aquatic resources and human use thereof;(ii)The philosophy adopted for control of inputs of persistent toxic substances shall be zero discharge; and(iii)The reduction in the generation of contaminants, particularly persistent toxic substances, either through the reduction of the total volume or quantity of waste or through the reduction of the toxicity of waste, or both, shall, wherever possible, be encouraged.(b)The Parties shall take all reasonable and practical measures to rehabilitate those portions of the Great Lakes System adversely affected by persistent toxic substances.3.Programs. The Parties in cooperation with the State and Provincial Governments, shall develop and adopt the following programs and measures for the elimination of discharges of persistent toxic substances:

(a)Identification of raw materials, processes, products, by-products, waste sources and emissions involving persistent toxic substances, and quantitative data on the substances, together with recommendations on handling, use and disposition. Every effort shall be made to complete this inventory by January, 1982;(b)Establishment of close coordination between air, water and solid waste programs in order to assess the total input of toxic substances to the Great Lakes System and to define comprehensive, integrated controls;(c)Joint programs for disposal of hazardous materials to ensure that these materials such as pesticides, contaminated petroleum products, contaminated sludge and dredge spoils and industrial wastes are properly transported and disposed of. Every effort shall be made to implement these programs by 1980.4.Monitoring. Monitoring and research programs in support of the Great Lakes International Surveillance Plan should be established at a level sufficient to identify:

(a)Temporal and spatial trends in concentration of persistent toxic substances such as PCB, mirex, DDT, mercury and dieldrin, and of there substances known to be present in biota and sediment of the Great Lakes System;(b)The impact of persistent toxic substances on the health of humans and the quality and health of living aquatic systems;(c)The sources of input of persistent toxic substances; and(d)The presence of previously unidentified persistent toxic substances.5.Early Warning System. An early warning system consisting of, but not restricted to, the following elements shall be established to anticipate future toxic substances problems:

(a)Development and use of structure-activity correlations to predict environmental characteristics of chemicals;(b)Compilation and review of trends in the production, import, and use of chemicals;(c)Review of the results of environmental testing on new chemicals;(d)Toxicological research on chemicals, and review of research conducted in other countries;(e)Maintenance of a biological tissue bank and sediment to permit retroactive analysis to establish trends over time;(f)Monitoring to characterize the presence and significance of chemical residues in the environment;(g)Development and use of mathematical models to predict consequences of various loading rates of different chemicals;(h)Development of a data bank for storage of information on physical/chemical properties, toxicology, use and quantities in commerce of known and suspected persistent toxic substances;(i)Development of data necessary to evaluate the loadings of critical pollutants or other polluting substances identified in the boundary waters of the Great Lakes System; and(j)Further development and use of reproduction, physiological and biochemical measures in wildlife, fish and humans as health effects indicators and the establishment of a data base for storage, retrieval and interpretation of the data.6.Human Health. The Parties shall establish action levels to protect human health based on multimedia exposure and the interactive effects of toxic substances.7.Research. Research should be intensified to determine the pathways,

fate and effects of toxic substances aimed at the protection of human health, fishery resources and wildlife of the Great Lakes Basin Ecosystem. In particular, research should be conducted to determine:

(a) The significance of effects of persistent toxic substances on human health and aquatic life; (b) Interactive effects of residues of toxic substances on aquatic life, wildlife, and human health; and (c) Approaches to calculation of acceptable loading rates for persistent toxic substances, especially those which, in part, are naturally occurring. 8. Reporting. The Parties shall report, by December 31, 1988 and biennially thereafter, on the progress of programs and measures to reduce the generation of contaminants in accordance with the principle in sub-paragraph 2 (a) (iii) above.

ANNEX 13 - POLLUTION FROM NON-POINT SOURCES

1. Purpose. This Annex further delineates programs and measures for the abatement and reduction on non-point sources of pollution from land-use activities. These include efforts to further reduce non-point source inputs of phosphorus, sediments, toxic substances and microbiological contaminants contained in drainage from urban and rural land, including waste disposal sites, in the Great Lakes System. 2. Implementation. The Parties, in conjunction with State and Provincial Governments, shall:

(a) identify land-based activities contribution to water quality problems described in Remedial Action Plans for Areas of Concern, or in Lakewide Management Plans including, but not limited to, phosphorus and Critical Pollutants; and (b) develop and implement watershed management plans, consistent with the objectives and schedules for individual Remedial Action Plans or Lakewide Management Plans, on priority hydrologic units to reduce non-point source inputs. Such watershed plans shall include a description of priority areas, intergovernmental agreements, implementation schedules, and programs and other measures to fulfill the purpose of this Annex and the General and Specific Objectives of this Agreement. Such measures shall include provisions for regulation of non-point sources of pollution. 3. Wetlands and their Preservation.

Significant wetland areas in the Great Lakes System that are threatened by urban and agricultural development and waste disposal activities should be identified, preserved and, where necessary, rehabilitated. 4. Surveillance, Surveys and Demonstration Projects. Programs and projects shall be implemented in order to determine:

(a) non-point source pollutants inputs to and outputs from rivers and shoreline areas sufficient to estimate loadings to the boundary waters of the Great Lakes System; and (b) the extent of change in land-use and land management practices that significantly affect water quality for the purpose of tracking implementation of remedial measures and estimating associated changes in loadings to the Lakes. Demonstration projects of remedial programs on pilot urban and rural watersheds shall be encouraged to advance knowledge and enhance information and education services, including

extension services, where applicable. 5. The Parties shall report by December 31, 1988 and biennially thereafter, to the Commission on progress in developing specific watershed management plans and implementing programs and measures to control non-point sources of pollution.

ANNEX 14 - CONTAMINATED SEDIMENT

1. Objectives. The Parties shall, in cooperation with State and Provincial Governments, identify the nature and extent of sediment pollution of the Great Lakes System. Based on these findings, they shall develop methods to evaluate both the impact of polluted sediments on the Great Lakes System, and the technological capabilities of programs to remedy such pollution. Information obtained through research and studies pursuant to this Annex shall be used to guide the development of Remedial Action Plans and Lakewide Management Plans pursuant to Annex 2, but shall not be used to forestall the implementation of remedial measures already under way.

Dredging for the purpose of navigation is addressed in Annex 7.2. Research and Studies.

(a) General. The Parties, in cooperation with State and Provincial Governments, shall exchange information relating to the mapping, assessment and management of contaminated sediments in the Great Lakes System. (b) Surveillance Programs. The Parties, in cooperation with State and Provincial Governments shall:

(i) evaluate, on or before December 31, 1988 and biennially thereafter, existing methods for quantifying the transfer of contaminants and nutrients to and from bottom sediments for use in determining the impact of polluted sediments on the Great Lakes Basin Ecosystem; (ii) review practices in both countries regarding the classification of contaminated sediments and establish compatible criteria for the classification of sediment quality; (iii) develop common methods to quantify the transfer of contaminants and nutrients to and from bottom sediments. Such methods shall be used to determine the impact of polluted sediment of the Great Lakes System. As a first step, biological indicators shall be developed to determine accumulation rates in biota from polluted bottom sediments; and (iv) develop a standard approach and agreed procedures for the management of contaminated sediments by December 31, 1988. (c) Technology Programs

(i) The Parties shall, on or before December 31, 1988 and biennially thereafter, in cooperation with State and Provincial Governments, evaluate existing technologies for the management of contaminated sediments such as isolation, capping, in-place decontamination and removal of polluted bottom sediment. (ii) The Parties, in cooperation with State and Provincial Governments shall design and implement demonstration projects for the management of polluted bottom

sediment at selected Areas of Concern identified pursuant to Annex 2. The design shall be based on the evaluation(s) made pursuant to sub-paragraph (i) above, the Parties shall meet by June 20, 1988 and jointly design a demonstration program and implementation schedule and report progress biennially thereafter. 3. Long-Term Measures. The Parties, in cooperation with State and Provincial Governments, shall also ensure that measures are adopted for the management of contaminated sediment respecting:

(a) the construction and the long-term maintenance of disposal facilities; and (b) the use of contaminated sediment in the creation of land. 4. Reporting. The Parties shall report their progress in implementing this Annex to the Commission biennially, commencing with a report no later than December 31, 1988.

ANNEX 15 - AIRBORNE TOXIC SUBSTANCES

1. Purpose. The Parties, in cooperation with State and Provincial Governments, shall conduct research, surveillance and monitoring and implement pollution control measures for the purpose of reducing atmospheric deposition of toxic substances, particularly persistent toxic substances, to the Great Lakes Basin Ecosystem. 2. Research. Research activities shall be conducted to determine pathways, fate and effects of such toxic substances for the protection of the Great Lakes System. In particular, research shall be conducted to:

(a) understand the processes of wet and dry deposition and those associated with the vapor exchange of toxic substances; (b) understand the effects of persistent toxic substances, singly or in synergistic or additive combination with other substances, through aquatic exposure routes on the health of humans and the quality and health of aquatic life where a significant source of these substances is the atmosphere, in accordance with sub-paragraph 4(b) of Annex 12; and (c) develop models of the intermediate and long-range movement and transformation of toxic substances to determine;

(i) the significance of atmospheric loadings to the Great Lakes System relative to other pathways; and (ii) the sources of such substances from outside the Great Lakes System. 3. Surveillance and Monitoring. The Parties shall:

(a) establish, as part of the Great Lakes International Surveillance Plan (GLISP) instituted under Annex 11, an Integrated Atmospheric Deposition Network in accordance with paragraph 4 below; (b) identify, by means of this Network, toxic substances and, in particular, persistent toxic substances, appearing on List No. 1 described in Annex 1, of those designated as Critical

Pollutants pursuant to Annex 2 and their significant sources in accordance with sub-paragraph 4(c) of Annex 12, and to track their movements; and(c)utilize this Network in order to:

(i)determine atmospheric loadings of toxic substances to the Great Lakes System by quantifying the total and net atmospheric input of these same contaminants, pursuant to sub-paragraph 3(a) of Annex 11;(ii)define the temporal and spatial trends in the atmospheric deposition of such toxic substances in accordance with sub-paragraph 4(a) of Annex 12; and(iii)develop Remedial Action Plans and Lakewide Management Plans pursuant to Annex 2.4.Components of the Integrated Atmospheric Deposition Network. The Parties shall confer on or before October 1, 1988, regarding;

(a)the identity of the toxic substances to be monitored;(b)the number of monitoring and surveillance stations;(c)the locations of such stations;(d)the equipment at such stations;(e)quality control and quality assurance procedures; and(f)a schedule for the construction and commencement of the operation of the stations.5.Pollution Control Measures.

(a)The Parties, in cooperation with State and Provincial Governments, shall develop, adopt and implement measures for the control of the sources of emissions of toxic substances and the elimination of the sources of emissions of persistent toxic substances in cases where atmospheric deposition of these substances, singly or in synergistic or additive combination with other substances, significantly contributes to pollution of the Great Lakes System. Where such contributions arise from sources beyond the jurisdiction of the Parties, the Parties shall notify the responsible jurisdiction and the Commission of the problem and seek a suitable response.(b)The Parties shall also assess and encourage the development of pollution control technologies and alternative products to reduce the effect of airborne toxic substances on the Great Lakes System.6.Reporting. The Parties shall report their progress in implementing this Annex to the Commission biennially, commencing with a report no later than December 31, 1988.

ANNEX 16 - POLLUTION FROM CONTAMINATED GROUNDWATER

The Parties, in cooperation with State and Provincial Governments, shall coordinate existing program to control contaminated groundwater affecting the boundary waters of the Great Lakes System. For this purpose, the Parties shall;

(i)identify existing and potential sources of contaminated groundwater affecting the Great Lakes;(ii)map hydrogeological conditions in the vicinity of existing and potential sources of contaminated groundwater;(iii)develop a standard approach and agreed procedures for sampling

and analysis of contaminants in groundwater in order to: (1) assess and characterize the degree and extent of contamination; and (2) estimate the loadings of contaminants from groundwater to the Lakes to support the development of Remedial Action Plans and Lakewide Management Plans pursuant to Annex 2;(iv)control the sources of contamination of groundwater and the contaminated groundwater itself, when the problem has been identified; and(v)report progress on implementing this Annex to the Commission biennially, commencing with a report no later than December 31, 1988.

ANNEX 17 - RESEARCH AND DEVELOPMENT

1.Purpose. This Annex delineates research need to support the achievement of the goals of this Agreement.2.Implementation. The Parties, in cooperation with State and Provincial Governments, shall conduct research in order to:

(a)determine the mass transfer of pollutants between the Great Lakes Basin Ecosystem components of water, sediments, air, land and biota, and the processes controlling the transfer of pollutants across the interfaces between these components in accordance with Annexes 13, 14, 15 and 16;(b)develop load reduction models for pollutants in the Great Lakes System in accordance with the research requirements of Annexes 2, 11, 12 and 13;(c)determine the physical and transformational processes affecting the delivery of pollutants by tributaries to the Great Lakes in accordance with Annexes 2, 11, 12 and 13;(d)determine cause-effect inter-relationships of productivity and ecotoxicity, and identify future research needs in accordance with Annexes 11, 12, 13 and 15;(e)determine the relationship of contaminated sediments on ecosystem health, in accordance with the research needs of Annexes 2, 12 and 14;(f)determine pollutant exchanges between the Areas of Concern and the open lakes including cause-effect inter-relationships among nutrients, productivity, sediments, pollutants, biota and ecosystem health, and to develop in-situ chemical, physical and biological remedial options in accordance with Annexes 2, 12, 14 and sub-paragraph 1(f) of Annex 3;(g)determine the aquatic effects of varying lake levels in relation to pollution sources, particularly respecting the conservation of wetlands and the fate and effects of pollutants in the Great Lakes Basin Ecosystem in accordance with Annexes 2, 11, 12, 13, 15 and 16;(h)determine the ecotoxicity and toxicity effects of pollutants in the development of water quality objectives in accordance with Annex 1;(i)determine the impact of water quality and the introduction of non-native species on fish and wildlife populations and habitats in order to develop feasible options for their recovery, restoration or enhancement in accordance with

sub-paragraph 1(a) of Article IV and Annexes 1, 2, 11 and 12;(j)encourage the development of control technologies for treatment of municipal and industrial effluents, atmospheric emissions and the disposal of wastes, including wastes deposited in landfills;(k)develop action levels for contamination that incorporate multi-media exposures and the interactive effects of chemicals; and(l)develop approaches to population-based studies to determine the long-term, low-level effects of toxic substances on human health.

TERMS OF REFERENCE FOR THE JOINT INSTITUTIONS AND THE GREAT LAKES REGIONAL OFFICE

1.Great Lakes Water Quality Board

(a)This Board shall be the principal advisor to the International Joint Commission with regard to the exercise of all the function, powers and responsibilities (other than those functions and responsibilities of the Science Advisory Board pursuant to paragraph 2 of these Terms of Reference) assigned to the Commission under this Agreement. In addition, the Board shall carry out such other functions, related to the water quality of the boundary waters of the Great Lakes System, as the Commission may request from time to time.(b)The Water Quality Board, at the direction of the Commission, shall:

(i)Make recommendations on the development and implementation of programs to achieve the purpose of this Agreement;(ii)Assemble and evaluate information evolving from such programs;(iii)Identify deficiencies in the scope and funding of such programs and evaluate the adequacy and compatibility of results;(iv)Examine the appropriateness of such programs in light of present and future socio-economic imperatives; and(v)Advise the Commission on the progress and effectiveness of such programs and submit appropriate recommendations.(c)The Water Quality Board, on behalf of the Commission, shall undertake liaison and coordination between the institutions established under this Agreement and other institutions and jurisdictions which may address concerns relevant to the Great Lakes Basin Ecosystem so as to ensure a comprehensive and coordinated approach to planning and to the resolution of problems, both current and anticipated.(d)The Water Quality Board shall report to the Commission periodically as

appropriate, or as required by the Commission, on all aspects relating to the operation and effectiveness of this Agreement.2.Great Lakes Science Advisory Board

(a)This Board shall be the scientific advisor to the Commission and the Water Quality Board.(b)The Science Advisory Board shall be responsible for developing recommendations on all matters related to research and the development of scientific knowledge pertinent to the identification, evaluation and resolution of current and anticipated problems related to Great Lakes water quality.(c)To effect these responsibilities the Science Advisory Board shall;

(i)Review scientific information in order to:

a.examine the impact and adequacy of research and the reliability of research results, and ensure the dissemination of such results;b.identify additional research requirements;c.identify specific research programs for which international cooperation is desirable; and(ii)Advise jurisdictions of relevant research needs, solicit their involvement and promote coordination.(d)The Science

Advisory Board shall seek analyses, assessments and recommendations from other scientific, professional, academic, governmental or intergovernmental relevant to Great Lakes Basin Ecosystem research.(e)The Science Advisory Board shall report to the Commission and the Water Quality Board periodically as appropriate, or as required by the Commission, on all matters of a scientific or research nature relating to the operation and effectiveness of this Agreement.3.The

Great Lakes Regional Office

(a)This Office, located in Windsor, Ontario, shall assist the Commission and the two Boards in the discharge of the functions specified in subparagraph (b) below.(b)The Office shall perform the following functions:

(i)Provide administrative support and technical assistance for the Water Quality Board and the Science Advisory Board and their sub-organizations, to assist the Boards in discharging effectively the responsibilities, duties and functions assigned to them.(ii)Provide a public information service for the programs, including public hearings, undertaken by the Commission and its Boards.(c)The Office shall be headed by a Director who shall be appointed by the Commission in consultation with the Parties and with the Co-Chairmen of the Boards. The position of Director shall alternate between a Canadian citizen and a United States citizen. The term of office for the Director shall be determined in the review referred to in subparagraph (d) below.(d)The Parties, mindful of the need to staff the Great Lakes Regional Office to carry out the functions assigned the Commission by this Agreement, shall, within six months from the date of entry into force of this Agreement, complete a review of the staffing of the Office. This review shall be conducted by the Parties based upon recommendations of the Commission after consultation with the Co-Chairmen of the Boards. Subsequent review may be requested by either Party, or recommended by the Commission, in order to ensure that the staffing of the Regional Office is maintained at a level and character commensurate with its assigned functions.(e)Consistent with the responsibilities assigned to the Commission, and under the general supervision of the Water Quality Board, the Director shall be responsible for the management of the Regional Office and its staff in carrying out the functions described herein.(f)The Co-Chairmen of the Boards, in consultation with the Director, will determine the activities which they wish the Office to carry out on behalf of, or in support of the Boards, within the current capability of the Office and its staff. The Director is responsible to the Co-Chairmen of each Board for activities carried out on behalf of, or in support of such Board, by the Office or individual staff members.(g)The Commission, in consultation with the Director, will determine the public information activities to be carried out on behalf of the Commission by the Regional Office.(h)The Director shall be responsible for preparing an annual budget to carry out the functions of the

Boards and the Regional Office for submission jointly by the two Boards to the Commission for approval and procurement of resources.

Revised: January 18, 1997 Maintained by Kevin McGunagle,

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